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PROCEEDINGS

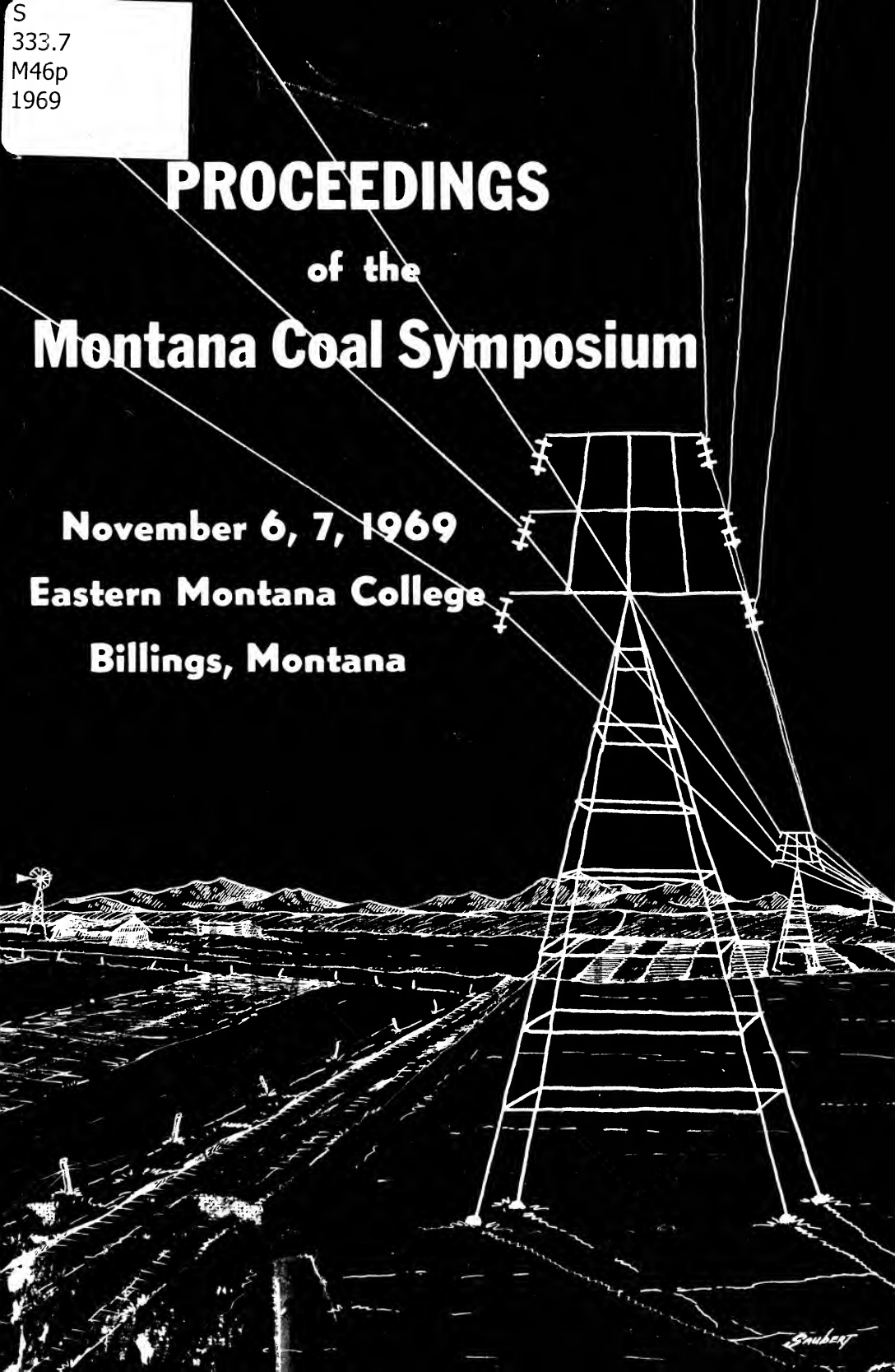
of the

Montana Coal Symposium

November 6, 7, 1969

Eastern Montana College

Billings, Montana



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PROCEEDINGS of the

MONTANA COAL SYMPOSIUM

at

Eastern Montana College
Billings, Montana

on

November 6, 7, 1969

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ACKNOWLEDGEMENTS

This COAL SYMPOSIUM was

-- sponsored by --

Senator Lee Metcalf
Senator Mike Mansfield
Representative Arnold Olson
Representative John Melcher
Governor Forrest Anderson

-- under the guidance of --

Program Chairman

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Executive Secretary to Senator Lee Metcalf

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The Proceedings were published January, 1970, by

Empire Printing, Inc.
1120 Sixteenth Street West
Billings, Montana 59101

Price per copy: $3.50, postpaid.

Bulk prices available, on inquiry to Dr. Clark.

TABLE of CONTENTS

Background Paper -- Vic Reinemer i
Welcome to the Montana Coal Symposium -- Stanely Heywood 1

Session I -- An Overview

Remarks by Moderator -- Roy E. Huffman 2
Introductory Remarks -- Governor Forrest Anderson 3
Energy and the Environment in the Years Ahead -- S. David Freeman 5
Coal Export by Wire -- Ken Holum 15
Coal Export by Rail -- John McGrath 20
Coal Export by Rail from Montana to Minnesota -- Elwood McGuire 21
A National Power Grid -- William E. Warne 26

Session II -- Electric Energy Requirements in the West

Remarks by Panel Moderator -- Henry G. Curtis 30
Power Potential and Requirements of the Northwest -- Robert B. Lisbakken 31
Future Electric Power Requirements of the Southwest -- Rod J. McMullin 34
Power Requirements of the Missouri Basin -- Fred G. Simonton 40
Future Planning for Power in the Missouri Area -- Neil L. Adams 43
Electric Energy Requirements in Nebraska -- Durwood W. Hill 45
Integration of Hydro-Thermal Power Supply -- William E. Trammershausen and R. B. Gallup 48

Session III -- Coal Mining and Exporting Techniques

Remarks by Panel Moderator -- Arnold J. Silverman 61
Moving Those 8500 BTU's -- Richard E. Miller 62
Strip Mining -- Edwin R. Phelps 65
Unit Trains -- Robert D. Pederson 68
The Importance of Slurry Pipelines -- Edward J. Wasp 73

Session IV -- Review of Resources and Their Relation to the Environment

Remarks by Panel Moderator -- Wilson F. Clark 78

Part 1 -- The Resource Base

Montana's Strippable Coal Resources -- Robert E. Matson 80
Industrial Water -- Harold Aldrich 89
Land - (Abstract of Remarks) -- Ted W. Schwinden 94

Part 2 -- Environmental Considerations

Environmental Considerations -- George W. O'Conner .. 95

Land Reclamation, as Viewed by a Coal Operator -- Thomas A. Gwynn 99

Conservation in the Use of Coal -- James Grahl 104

Coal Industry at What Price? A Rancher's View -- Wallace D. McRae 108

Environment and Economics Go Hand in Hand -- Gordon McGowan 111

Coal Use and Air Pollution -- Benjamin F. Wake 114

The Need for Coal Lands Salvage Archaeology -- Stuart W. Conner 118

A Legislators Dilemma -- E. W. Christensen 122

Seizing the Opportunity for Regional Environmental Planning -- George Darrow 126

Remarks on Environmental Planning -- Theodore J. Wirth 130

Abstract of Luncheon Address

Montana's Coal Resource Potential -- Congressman John Melcher 133

Session V -- Emerging Technology

Remarks by Panel Moderator -- Robert O. Marritz 135

Part 1 -- Magneto Hydro Dynamics

Magneto Hydro Dynamics -- Richard A. Rosa and William D. Jackson 136

Engineering Aspects of Magneto Hydro Dynamics -- Kenneth A. Roe 154

Part 2 -- Gasification and Liquefaction

Project Gas, Oil, and Power -- Neal Cochran 170

Filling the Gap with Coal -- David J. Kull 176

Coal Gasification -- Frank C. Schora 178

Prospects for Coal Liquefaction -- Carl B. Herrington 183

Part 3 -- The H-Coal Process

Convert Coal to Liquid Fuels with H-Coal -- Clarence A. Johnson 191

Summary of the Montana Coal Symposium -- Perry F. Roys 201

Concluding Remarks -- Vic Reinemer 206

BACKGROUND PAPER

MONTANA COAL SYMPOSIUM

Montana's vast coal reserves offer an opportunity for economic development unprecedented since the discovery of the "Richest Hill on Earth" at Butte. But, as was the case in Butte, development poses threats to Montana's beautiful environment that cannot be ignored. The purpose of the Montana Coal Symposium will be to look at how modern technology can best utilize Montana coal -- and, at the same time, how the development can take place with minimal damage to the environment.

Coal offers two commodities to modern man: the energy that can be produced through burning it or its products, and the chemicals that can be derived from it. The greatest potential today appears to be a conversion of coal to energy or energy products -- although chemical production could very possibly be an auxiliary industry.

Energy can be secured from coal in two basic ways. One is conversion to electrical energy, and this industry today is by far the largest user of coal in Montana. The other is conversion of coal to synthetic hydrocarbons -- gasoline or a natural gas substitute -- and this represents a great potential, although the necessary technologies are still in the developmental stage.

POWER FROM COAL

The Nation's power needs, especially in heavily-populated areas, are growing rapidly. Markets in the populated Midwest and in the Pacific Northwest are burgeoning. These areas a short time ago were looking to the atom for the future's major power source. However, rapidly escalating nuclear fuel and plant costs, plus a number of unsolved conservation problems, have cast a shadow over the future of nuclear generators -- at least for the next few years.

Montana coal may fill the gap. Preliminary studies show extra- or ultra-high-voltage transmission lines -- "electrical superhighways" -- between the Pacific Northwest and the Midwest to be economically feasible. The lines will probably pay for themselves through allowing giant bulk power exchanges between the two regions. When you add the economic benefits of low-cost Montana coal to the formula, the lines become even more desirable. Not only would they provide for power exchanges between the two regions, but they also would carry power produced in Montana. Montana coal would be "shipped by wire" to these two great markets.

Power has traditionally been produced from coal through burning of coal to produce steam to turn a turbine -- which, in turn, provides torque to a generator. This technique has disadvantages.

This background paper on the Montana coal symposium at Eastern Montana College, Billings, Montana, was prepared at the request of members of the Montana Congressional delegation and the Governor of Montana, by Mr. Vic Reinemer, and for distribution to program participants prior to the Symposium.

It is not very efficient (although it is more efficient than the similar process that is used in nuclear plants) and it creates thermal pollution -- the heating of water that is used to condense the steam. This kind of pollution can be devastating to the balance of life in a stream or lake or even in an ocean, at least locally.

A promising new technique that might eliminate thermal pollution, or reduce it greatly, is magnetohydrodynamics, called MHD for short. Briefly, MHD converts burning coal directly to electrical energy without any of the intermediate steps. It is far more efficient than the old steam-turbine technique and it thus does not create as much waste heat. The Office of Coal Research is ready to go ahead with an MHD pilot plant research program if it can get appropriations. The program has been endorsed by the Office of Science and Technology and by the Montana Congressional Delegation. Montana might be an ideal site for the pilot plant.

Power from Montana coal does not necessarily have to be produced in Montana. There is also a great potential for shipping coal via rail to populous markets. Already Montana coal is going to northern Minnesota for this purpose. That the coal is hauled 800 miles, and is still competitive, proves its strength in the market place.

SYNTHETIC FUELS

Coal is mostly carbon. Add hydrogen and you have hydrocarbons, the basic of all modern fuels, including natural gas, gasoline and fuel oils.

Hydrogen can be added to coal this way. The Germans relied on "Braun coal," a substance much like Montana lignite, for producing fuels when they ran short of petroleum during World War II.

The Nation's petroleum will not last forever, even with the fabulous Arctic Slope discovery in Alaska. Oil companies know this, and they and the Office of Coal Research have been working on techniques to "hydrogenate" coal into hydrocarbons. A number of processes have been developed for this purpose -- OCR recently issued a report on a Cresap, West Virginia, pilot plant operated by Consolidation Coal Company. There is little doubt now that an economic process will be developed, and oil companies have been securing leases on coal in Montana, Wyoming, and elsewhere.

A Rapid City, South Dakota, pilot plant will be used to study the potential for conversion of coal to a substitute for natural gas, the reserves of which are rapidly being depleted.

COMBINED PLANTS

Combined electric and synthetic hydrocarbons plants may offer a great potential for Montana coal. It is possible that "char," a byproduct of the coal-to-gasoline process would make a good fuel for powerplants.

Chemicals might also be produced in such a plant. Petroleum in recent years has become the major source of such chemicals, but coal may once again be a major contender in the chemicals industry.

WATER

One of Montana's aces in the hole in attracting coal-based industry is water. The State has abundant supplies -- from the Yellowstone and Missouri rivers and their tributaries. Yellowtail Reservoir on the Big Horn River is a major possibility, and Fort Peck Reservoir on the Missouri may also be.

Water may be the key to coal development. Every process described above requires cooling water and water for other purposes -- although MHD needs less than most.

CONSERVATION

There are large conservation problems associated with coal production and development, but they can be solved with modern technology.

Coal in Montana in modern times is obtained from strip mines. These mines create deep gullies and accompanying mounds of earth, called "spoil banks." A major conservation issue is the extent to which countryside must be restored after strip mining. Not only are the spoil banks unsightly, but they also often contribute to water pollution and other kinds of environmental damage. Modern technology has developed ways to level the spoil banks -- but the cost is high, and choices must soon be made.

Burning coal for any purpose creates "fly ash," a fine, abrasive residue, and various gaseous pollutants, including sulfur and nitrogen oxides. Montana coal possesses a tremendous advantage over other coals in that its sulfur content is very low and it produces less of the damaging sulfur oxides.

Nonetheless, there will be a problem of air pollution from power plants and other coal-using installations. Technology can now remove the particulate pollutants, the fly ash, without too much difficulty. But processes for removing the gaseous pollutants are still embryonic. With increasing nationwide, even worldwide, air pollution, it is necessary that solutions be found soon, even for installations that will be located on remote Montana prairies.

Eastern Montana, wherein most of the coal reserves lie, is an especially rich paleontological and archeological field, with ancient remains of prehistoric Indian life and rich fossil beds, which would be ruined by indiscriminate strip mining.

WELCOME TO THE MONTANA COAL SYMPOSIUM

Stanley J. Heywood

The Campus is honored today by the attendance at the Montana Coal Symposium of so many distinguished leaders of government, industry and education -- and, by the way, these are not exclusive -- it is possible to have a little government and industry in education as well as a little education in government and industry.

Many things in life are two-edged swords. You swing them one way and they produce untold wealth and abundance, cutting down the necessary waste and making it profitable for the many; but on the reverse trip they can, in fact, destroy the holders.

Natural resources have this potential for growth on the one hand and destruction on the other. You are gathered here to consider one of these natural resources and it is a resource that has been known for a long time -- Coal. We know that it can't be used indiscriminately but used it can be, and with adequate safeguards, is a friend of man.

Your discussions in this symposium and your interest in a problem that is Montana's, but which goes far beyond even our broad area, are vital. The general citizenry, some of whom know about the questions and some who do not, some who care and others who care not, are dependent upon you for some excellent answers for the survival of our environment.

As one of these citizens who knows a little and cares a lot, I wish you a most successful meeting. I offer you the friendliness and hospitality for which Eastern Montana College is noted. We are pleased to have our faculty involved and we hope that you will return to our campus often.

Dr. Stanley J. Heywood, President, Eastern Montana College.

AN OVERVIEW

R. E. Huffman
Moderator

We live in a world dominated by science and technology. Continuing expansion of our scientific base and the development of useable technology provide the foundation for our affluent society. A growing population with growing demands on space and resources of all kinds suggest that there will be no end to the challenges to science and technology. All of the results of applying science and technology, however, are not beneficial to every individual and many developments are questioned by society.

Meeting the energy requirements of a growing population and its demands that are ever greater in amount and complexity, is a problem of considerable magnitude. The physical and economic considerations involved in transforming a coal resource to useable energy are not simple. The relationship to economic development in a region needing development is obvious. The problem is complicated by the fact that our affluent society is placing increasing emphasis on esthetic considerations.

We are faced, then, with a conflict between developmental values and environmental values. It is imperative that an accommodation be arrived at to resolve this conflict. Preservation of environmental values is not without cost. Such costs may be direct expenditures or they may be measured in economic values that are foregone. The development of an adequate economic base is necessary to the growth of a society that can afford to think in terms of preserving environmental values.

So, in our world dominated by science and technology, the challenge is to develop and use technology that will alleviate the undesirable effects of other technology. The agenda of this Symposium suggests that considerable attention will be directed to resolving the conflict between developmental values and environmental values. Progress in this direction will be a major contribution to the future of Montana.

Roy E. Huffman, Vice President for Research, Montana State University, Bozeman, Montana.

INTRODUCTORY REMARKS

Governor Forrest Anderson

We who live and work here in Montana sincerely welcome you to this important Symposium on coal resources and their development.

Even a cursory review of history demonstrates that one common but essential element in the development of any major industrial complex has been cheap power. The American experience substantiates this observation.

In the last 70 years, as power of all types has become more available, we have witnessed an economic revolution.

Where once our economy was almost completely agricultural, and therefore relatively simple and labor intensive, the economy is now almost completely industrial, and therefore, highly complex, interdependent and capital intensive.

To those in the mainstream of American economic life, the benefits of this revolution have been substantial, in fact, power has proven to be the elixir of the modern age, transforming raw materials into the goods and services our affluent society has come to expect.

Yet of all forms of power, none has proven more versatile and convenient than electrical energy -- so convenient that we often fail to realize its importance, except when we have power failures, such as the massive blackout in the eastern United States.

Because of its desirable attributes, the demand for electrical power is rapidly increasing. To understand why, one only has to list the number of appliances in the home that did not exist 20 years ago, or the number of industrial operations previously done by hand that are now done automatically.

At present, the need for electrical energy in the United States is doubling every 10 years, and the rate of increase will undoubtedly accelerate. Consider, for example, the increase in power needs if there is mass acceptance of an electric automobile, or if desalination technology is improved even slightly.

But the growth in demand is severely testing our ability to provide an adequate supply, as the power shortage in New York this summer dramatically illustrates. New hydro-power sites are almost a thing of the past; accessible oil and gas reserves are not adequate to keep pace even with present demands; and nuclear power, because of cost and environmental problems, still appears to be further in the future than was anticipated.

As a consequence, the immense coal reserves in the Western states are beginning to be tapped for conversion into electrical energy. As of October, 1969, power plants planned or under construction in the western states will produce 18,900 megawatts of electricity and utilize 47 million tons of coal every year.

However, Montana has yet to receive a substantial share of the growing investment in coal-fueled power plants. This is unfortunate for two reasons.

One, our state is in need of new, job-creating, capital investment. I have stated before that per capita personal income in Montana has declined from 113 percent of the national average in 1948 to 85 percent in 1958. Our working age population has declined from 86 percent of the total population in 1950 to 47 percent in 1968, resulting in a much narrower tax base.

These two factors mean that Montanans are simply unable to command the same level of goods and services as people in the rest of the nation. We tend to view this situation with indifference right now, for we are compensated by an environment and way of life that blunt the full effects. If nothing changes -- if this economic decline continues -- the future promises inadequate highways, schools, and medical and governmental services. The future cost of living in Montana may well be a prohibitively low standard of living.

The lack of investment in coal-fueled power in Montana is also unfortunate because we have two very valuable resources -- coal and water -- which are not being fully utilized.

If our nation's future economic growth depends on the continued availability of cheap power, and if the continued availability of cheap power depends on more efficient use of decreasing resources, a failure to utilize Montana's resources is a waste the country can ill afford.

Yet we cannot be so committed to economic growth that we will pay <u>any</u> price to engender coal development in the state. We are well aware that the technology which allows us to efficiently strip away mountains of coal, or to convert coal to electrical energy can, like all technology, <u>create</u> as well as <u>solve</u> problems.

The devastation of the land and pollution of the air and water which occurred in the eastern United States must not occur here.

Montanans have a right to expect that cost-benefit analyses will be conducted on the alternative uses of our resources. For instance, what are the benefits and costs, both human and economic, of having the land as it is, or of strip mining for export, or of constructing huge power plants?

We may discover from such analyses that the state should give some tax or other consideration to projects that involve power plants within the state, or perhaps even more to power companies that encourage industrial development through lower rates. Or, we may find that projects which are based on the long standing tradition of merely exporting raw materials are not worth the total cost.

In any case, it is my desire that this symposium mark the beginning of a reasoned examination and discussion of the myriad questions surrounding coal development -- the practice of basing decisions on ignorance, myopic self-interest, and emotion has too long plagued our state.

I also hope that your efforts in connection with the symposium will be rewarded by a Montana more capable of meeting the demands of its people for a better society -- a result of mutual advantage to all.

ENERGY AND THE ENVIRONMENT IN THE YEARS AHEAD

S. David Freeman

It is a distinct privilege and a pleasure to keynote this Montana Coal Symposium. From my vantage point in government, I see scarcity amidst abundance in energy supply. And I also see the problems of environmental protection in the energy field which have been neglected in the past. This Symposium focuses attention on solutions to both problems. Montana coal is part of that abundance which can make more of a contribution to a tight energy supply in the years ahead. And by recognizing the potential for damage to the environment, this Symposium can help shape measures that will avoid the insults to the environment that have accompanied coal production in the East.

I have a personal reason for being here aside from my admiration and friendship for the sponsors of this Symposium. I was born and grew up in another region of the country with natural resources that were put to the use of the nation. And I see a broad parallel between Montana coal and the water power resources of the Tennessee River, not in terms of ideology or government organization, but rather in the possibility of strengthening the nation by developing a regional resource. I am a personal witness to benefits to the region and the nation at large of planned and orderly development of the natural resources of the Tennessee Valley. The opportunities in Montana and throughout the Rocky Mountain region are, if anything, much greater. I am, therefore, most pleased to participate in this Symposium which is already a success because it has brought widespread attention to the fact that you have here in Montana an energy resource that dwarfs the imagination. And that you also have recreational assets and a beautiful and clean environment that you are determined to protect.

In trying to visualize for myself the size of the coal resource here in Montana, I gained some perspective by a comparison I would like to share with you. The 14 billion tons which are considered capable of economic strip mining alone constitute an energy resource as large as the entire nation's total proven reserves of natural gas, which now constitutes the supply for 31 percent of our total energy market. I remember when helping complete the Federal Power Commission's National Power Survey in 1964, being intrigued by the fact that there is more coal west of the Mississippi River than to the east. But I certainly didn't realize how much more there was.

As the keynote speaker, I would like to register a complaint with the sponsors of this Symposium. The Background Paper which you distributed in late September was such an excellent summary that it identifies all the major considerations affecting Montana coal. And if there are any areas untouched, the program which follows is jam-packed with a score of well-known experts who will explore all of these opportunities and problems areas in depth.

But I am not easily discouraged and I do believe that it may be useful to provide a broader perspective for the discussions

S. David Freeman, Director, Energy Policy Staff, Office of Science Technology, Washington, D.C.

which will follow. Energy and the Environment in the Years Ahead is a very big subject -- and the Montana soal resource may not look like such a tall mountain if we place it alongside the much higher peaks of energy demand which the nation will require in the years ahead.

Before looking into the future, I think it might be instructive to spend a minute or two looking back, because history is usually helpful in analyzing the future. We often forget the very recent origin of large-scale use of fossil fuels in this nation. As recently as 100 years ago, wood still provided 75 percent of this nation's energy supply. It was the Industrial Revolution that triggered the large-scale use of energy and it was coal that was the primary source. By the turn of the century, coal had pretty well displaced wood as our source of energy and accounted for about 70 percent of our energy supply.

Through 1920 coal was king, supplying nearly 75 percent of our energy in the first two decades of this century. After 1920 coal's share of the energy market deteriorated rather rapidly as first oil products, then natural gas, and more recently atomic energy have joined the energy family in competition with coal. The coal industry's share of the energy market fell from 75 percent in 1910 to a low point of about 22 percent in 1962. Since then it has been holding its own and perhaps gaining somewhat.

At present, the United States relies on three primary sources of energy -- oil, natural gas, and coal -- with hydroelectric and nuclear energy making relatively small contributions. Last year, oil supplied about one-half of our energy needs -- 44 percent. Natural gas accounted for almost one-third -- 31 percent. Coal was the source of 21 percent of energy consumed, and the remaining 4 percent was supplied by hydropower, with nuclear energy's share negligible.

It may be useful to indicate very roughly the end uses to which these primary energy sources are utilized. About 25 percent of all our energy is used for transportation -- automotive, air, and rail. This market is presently served exclusively by oil. Another 22 percent is utilized in generating electricity. Here coal is king, with natural gas and oil sharing this market, but they will be making room for nuclear power in the future. Almost half of the energy market is in the form of heat supplied by fossil fuels for residential, commercial and industrial establishments. About 10 percent of our energy resources are used as raw materials for the petrochemical industry and for other non-energy uses, and this is a very fast-growing market.

Last year the United States used the energy equivalent of 10.6 billion barrels of oil or 2.4 billion tons of coal. These numbers are so large as to be meaningless, but they do give some indication of the scope for growth available to coal if it could tap the present markets for oil and gas which account for 75 percent of the total. One rough way to visualize this amount of energy is to assume that each and every car, truck and bus in the United States has hitched behind it a trailer carrying about 20 tons of coal. This coal would be roughly equal to our energy requirements for a year. The representation is appropriate in another way. The proliferation of motor vehicles provides a graphic picture of the widespread nature of energy use, so we get a rough idea of where the energy is used.

Some feeling for the rate of growth in energy use can be portrayed if we realize that in the next 20 years this nation will probably consume more energy than has been consumed in the previous 70 years of this century. If we look to the past, all of the energy that was consumed in this nation prior to this century would not equal next year's consumption.

The most striking fact about our energy resources is that while oil and gas dominate the energy market, and will continue to do so for the foreseeable future, they are the two energy sources for which there are the smallest known potential supplies. U.S. oil and gas reserves are only a small fraction of the energy content of coal reserves. On a Btu basis, the energy in coal reserves is at least 10 times as large as natural gas and oil. In terms of resources to current production ratio, the disparity is at least 30 to 1.

In broad terms, U.S. energy resources of natural gas and oil are sufficient to meet growing needs for decades, but certainly not centuries. But looking to the future, as I have mentioned, we need not think of coal separately from oil and gas, for we are confident that it is technically possible to convert coal into liquid or gaseous form, although it is not yet economical to do so. After all, "coal oil" was used to run the first internal combustion engines, and we may well come full circle in the next decade.

For the end uses requiring gas or oil in the future, natural sources can be supplemented not only the the vast reserves of coal but also by shale oil reserves. The rich shale oil reserves are very large -- many times the size of our natural oil reserves -- but probably smaller than the total recoverable coal. There are also oil reserves in the tar sands which constitute another huge oil resource, located primarily in Canada.

While our resources are great, so are future demands. We have been examining existing forecasts of future energy demands and find that even the best of them are already outdated by the vast changes that are taking place in our energy economy. And most of these changes point to greater, not lesser, use of energy. But accepting for the moment existing projections which may not fully reflect these new factors, this nation will consume almost 3 times as much energy (2.8) in the period 1968-2000 as it did in the prior 32 years. This cumulative total is in the range of the energy equivalent of 590 billion barrels of crude oil or perhaps you'd prefer me to say 170 billion tons of average grade U.S. coal. Of course, this market will be shared by nuclear energy, natural gas, possibly shale, and to a small extend, hydropower as well as by crude oil and coal.

Most existing forecasts suggest that crude oil will continue to be the largest source for the remainder of this century and all agree that hydro's share will be quite small, that shale's role is uncertain, and that coal, natural gas, and nuclear energy will have appreciable market shares. But the size of the energy market and the respective shares of the competitors are large question marks. The various sources will be competing not only with respect to price and convenience, but increasingly with respect to the form of energy which can meet the nation's needs with minimum damage to the environment.

I spoke earlier of a tight energy market and we can see that future demands are tremendous. We should also recognize that energy is not particularly useful unless it can be brought to the consumer at a reasonable price, including the cost of environmental protection. It is quite possible that some of our energy reserves are no more relevant than gold, which is found in dilute form throughout the crust of the earth and in the oceans but cannot be produced profitably even though its value is $35 for just an ounce.

What is missing, and what is crucial, in any assessment of our resource base is the cost of producing, transporting, and utilizing those various energy sources in the quantities needed in the coming years. The term the economists use is "supply schedules." How much coal do we have at $14 a ton? How much gas and oil at existing costs? And by costs I include the cost of environmental protection.

It is, therefore, perhaps misleading to dwell on gross figures that suggest that we can be relaxed about energy supply. At any given moment there is a tremendous demand for the supply of energy to meet next year's growth at prices hopefully lower than, but certainly at or near, existing levels. To the utility executive planning a new fossil-fueled power station in the East, it is small comfort to be told that there are hundreds of billions of tons of coal in the ground when he has difficulty finding a 100-million-ton block within an economic distance of the plant site that can assure him of economical fuel over its life. Nor are these reserves any comfort to a utility wishing to comply with air pollution control standards if low sulphur fuel or stack gas cleaning technology is not available. And it is frustrating to the natural gas distributor wishing to expand service to new customers to know of the vast resources that are yet to be developed if he cannot obtain all of the additional gas that he wishes to purchase at prevailing rates. Unfortunately, these examples are not hypothetical in the present circumstances.

There is another fairly obvious reason for concern even though our resource base is large. We are in the midst of a great awakening as to the impact on the environment associated with energy use. This increased concern for the environment is occurring at a time when growth in energy consumption is already straining the capabilities of those who produce, transport, and distribute it, as well as their equipment manufacturers. When we consider the problems we face in the coming years are energy demands grow and environmental concerns intensify, it may not be an exaggeration to speak of a coming crisis amidst abundance in energy resources.

It seems to me that what I have said suggests that there may be very limited amounts of really low-cost resources to satisfy future energy needs. If this is true, then in a real sense, every ton of coal and other energy source available in large, low-cost concentrations are precious. It is most likely that as we dig deeper into our storehouse additional supplies will be more difficult to obtain. Hopefully, new technology will enable us to keep costs down, but we have every incentive to increase the efficiency with which we utilize our energy resources.

The enormity of future energy needs has an important lesson to teach. It means that those Americans who for decades have been

concerned with the conservation of our natural resources were right. There is only a limited quantity of fossil fuels in the ground. And while the quantities are large, looked at from Mother Nature's time perspective, our high energy civilization may concume them in one big luncheon.

More efficient conversion systems are needed to stretch out the life span of our lowest cost energy resources. Such systems will also help to alleviate the associated air and water pollution problems. One way to cut down on air pollution is to burn fewer pounds of coal or oil, to generate a given quantity of electricity, or to drive a car a given number of miles.

The thermal-effects problems at large electric power plants are vivid reminders that even our most modern plants for converting energy into electricity are only 40 percent efficiency. Present nuclear plants have even lower efficiency but the development of breeder reactors will improve the efficiency of nuclear plants. Improvement in efficiency for fossil plants, such as is promised by open-cycle MHD generators, could go far toward conserving low-cost fuel and alleviating the environmental effects of inefficient conversion. Our Office recently published a report of a distinguished panel which examined the MHD concept and urged that we proceed with the necessary research.

I referred earlier to the increasing concern for protecting the environment and I'd like to explore that concern for a few moments. We now possess the capability of exploring the universe. Viewed from outer space, the earth is but another space ship also on a perilous journey. And on our "ship," human life is made possible only by the fine crust of soil which covers the earth and the thin blanket of air which surrounds it. Viewed from this perspective of outer space, our most precious -- and perhaps our most limited -- natural resources are the surface of Mother Earth herself and the air we breathe. The most limiting factors in the future production of energy may well be whether we can preserve the face of the earth and cease contaminating the air we breathe. These hard facts of life seem to me to be crucial to any analysis of future energy supplies.

Minimizing these environmental impacts seems to me to be the overriding challenge which is crucial to the future of our use of energy. It is a problem that will command our best research talent, large funding, strict enforcement of regulatory standards, long-range planning and, above all, a determination and commitment by the American people and all levels of government that the job must be done.

The environmental and health and safety problems seem to play no favorites in the energy field. They are present no matter which form of energy we examine. At the production end there are serious health and safety problems in the mining of coal, but similar problems exist in the mining of uranium. Strip mining of coal has left many a scar on the landscape. And recent experience at Santa Barbara suggests that producing oil from the rich offshore reserves in some areas presents far greater potential hazards to the marine environment than we had previously assumed.

Transportation of electricity involves the use of large, extra high voltage lines, which are increasingly met with opposition from those who consider them an intrusion on the landscape.

Natural gas transportation involves the safety hazard inherent in pipelines under high pressure through populated areas. And the transportation of oil by tankers poses a threat to the marine environment and shorelines when accidents inenvitably occur.

The burning of fossil fuels -- whether in automobiles, industrial plants or otherwise -- is the major element in the nation's air pollution problem. Fossil-fueled electric power plants pose major environmental concerns of air and water pollution, as well as scenic concerns. Nuclear plants promise to alleviate air pollution, but their special problems of radiation emissions and waste heat disposal are receiving increasing attention from the public.

When we speak of environmental problems in the use of energy and the need for increased efficiency, we cannot ignore the use of energy in the transportation field, for it is in the city streets where we come face to face with the air pollution problem every day. It is undoubtedly a subject for another speech, but I did not want to omit mention of perhaps the major area for improving the role of energy in meeting the needs of modern society.

Certainly the energy industries have a "full plate" of environmental problems to add to the difficulties of matching available resources with market requirements.

It is true, of course, that for many thousands of years man has been making his mark upon the face of the earth and that air pollution is as old as the process of combustion. But, as we have seen, past energy use is but a tiny fraction of the projections for the future. And we have already reached the point where, to a traveller from outer space, the first signs of life on this planet are the huge masses of polluted air which hover over the major cities of the world.

I do not believe that anyone can look at the projections of energy use that will be required in the next few decades without concern or perhaps alarm. In the process of satisfying the enormous appetite for energy in our increasingly mechanized world, we could easily destroy much of the beauty of nature here on earth. If we don't take remedial action, we could so intensify the problems of air and water pollution that our use of energy could become a curse rather than a blessing. I believe we can -- indeed, we must -- develop economic solutions to these environmental problems. But they will not be developed unless we recognize the problems and devote the resources necessary to develop solutions.

We are faced with a real dilemma posed by our growing appetite for energy and the environmental problems created by its use. I believe anyone who is really concerned with environmental protection must take a serious look at the alternatives because a further deterioration of the environment seems inevitable if we do not translate our concern into protective actions.

Since it is impossible to utilize energy without at least some disturbance of the environment in mining, transporting and utilizing energy, perhaps the first question to ask is how can we reduce the volume. Is all this growth in energy use really needed? We know, of course, that the increase in population is

one of the major reasons that energy use will increase in the future. If we are really serious about checking the deterioration of our environment, it might be fair to say that we should begin a program of population control here in the U.S. Dr. Jean Mayer, the President's nutrition adviser, published an interesting article recently in which he pointed out that an individual in an affluent society such as the United States or Western Europe is responsible for a much larger drain on resources and deterioration of the environment than a person in an underdeveloped nation.

Pollution is a by-product of affluence, not poverty. This rather obvious fact is overlooked by most people who think of population control as a program necessary only where there is a shortage of food. Population control, it seems to me, is one item that should be included in any program to preserve the environment. Many of our environmental problems are very much related to the size of the population and if population continues to grow, we may be overcome by sheer numbers no matter how hard we try to protect the environment.

But we must not delude ourselves. While population control may be a factor in long-term environmental protection, it is not going to help us solve the problem in the next two decades. The 200 million Americans already born are occupying larger homes which require more heat in winter and they are increasingly using energy to keep cool in summer. A family which operates two automobiles, or perhaps three, consumes more energy for transportation. Each new household convenience is a consumer of energy. As industry becomes more computerized and more mechanized, consumption of energy tends to increase. Increased productivity often requires more intensive use of energy.

Energy use is thus outstripping population growth and the increased requirements are fundamental to our way of life. After thousands and thousands of years, during which man's struggle was merely for bare survival and simple comforts, we have reached the stage today where most people in this country are trained and paid for thinking. An abundant supply of low-cost energy is essential to continuing this trend, which is freeing man from the burdensome chores of living and enabling him to spend more and more of his time enjoying the pleasures of affluence, leisure, and education.

The question before the nation then is not energy or a liveable environment, because without energy our total environment would not be liveable to the modern man. The question, in my view, is much simpler -- are we going to take the necessary measures to obtain our energy supply with a very minimum damage to the environment so as to reduce pollution to levels with which we and our children can live?

What is necessary is to make environmental protection an integral part of our design of energy supply systems just as technical efficiency has been in the past. And, of course, the two are to some extent interrelated, as we have already noted, because increased efficiency is one sure way to cut down on the by-product of the combustion process. Surely if we apply the nation's research talents and its engineering ingenuity to the safety of underground mining, the reclamation of strip-mined areas, the curtailment of oxides of sulfur and other by-products of combustion, the placing of transmission lines underground and

other needed measures, we can develop economic solutions with which we can live. I for one believe that we can obtain our needed energy supplies and have clean air, too, but it is going to take action -- not words -- to make it happen.

One action which this Symposium should help spur by one means or another is assurance that the strip-mining of coal in Montana includes a requirement to restore the land. We have hundreds of thousands of acres of land in the East that have been stripped not only of the coal beneath but of all nature's protective growth and left as an eyesore and source of erosion, the costs of which the public at large and our future generations must bear. The cost of restoration is relatively small if required when the mining is done. A strong legal requirement to that effect is really basic if the coal resources in Montana or any other state are to be strip-mined with minimum cost to the nation.

There are other actions that can be taken to apply what we have already learned to obtain energy supplies and minimize environmental damage. These actions will cost money, but what is overlooked is that failure to take them will cost even more. The only difference is that the larger bill is paid by the public at large and not the energy industries and its consumers. I for one believe we must continue to strive for low-cost energy, but we are really fooling ourselves if we think that energy is low-cost when it doesn't include the cost of protecting the environment. It is only when environmental costs are included that the utilities will have the incentives to develop economical solutions and the consumer will be able to choose the form of energy which really is lowest cost including the cost of protecting the environment.

The costs of environmental protection are beginning to be reflected in today's energy market through the thermal pollution standards set up by the Water Quality Act, the air pollution standards being adopted under the Air Quality Act, the AEC's standards for nuclear plants, strip mine reclamation laws in many states, a strong coal mine safety act now being enacted, the Natural Gas Safety Act and others. But these statutory schemes can only require us to utilize technology that is available. For coal to continue its recent rate of growth beyond the next few years will require new mining methods for underground mining to meet health and safety requirements, economical technology to remove sulphur oxides and other stack gases, and more efficient power methods such as MHD. Economical means of converting coal to natural gas or oil could unlock new markets larger than all of coal's present markets.

The key to success in these areas of prime interest to coal -- miner health and safety, air pollution control, more efficient coal generating methods, and conversion to gas or liquids -- is research and development, a subject which the industry has understandably neglected during the years it was struggling desperately for survival against new competitors. If the coal industry is to remain a vigorous competitor for the gigantic energy markets of the future, then it must mount a more extensive research and development effort. The federal government should be a paying partner in this research effort, but it cannot do the job alone. And federal funding is much more likely if the research efforts are also attracting funds from the industry most vitally concerned.

The federal government has neglected its responsibilities for research in the fossil fuels, but so has the coal industry. We must both turn the corner together if the nation is to derive the benefit of the enormous resources of coal which could play such a useful role in meeting the energy needs of the future.

As the coal industry looks to its future, the entire energy market, not just electric power production, is open territory for coal. I believe that penetrating the market for energy in liquid and gaseous form is essential to coal's long-term growth. This is true because no matter how hard coal tries, somewhere down the road -- sooner or later -- there will undoubtedly be more and more nuclear power plants that will be able to undersell it. But, even if the growth in the electric power market for coal were assured to continue, there is every reason for coal to make a play for part of the oil and gas market, which today is over three times as large as the market for coal.

I have tried today briefly to sketch out the broad dimensions of future energy needs and envision mental concerns. Here is how I think they relate to coal's future. The need for energy is large and it is growing fast. Our coal resources are large and the cost of coal in place is very small indeed. One need not spend large sums exploring for coal. We know that there are vast resources available even though we are not at all certain as to the quantities available at particular prices. If we devote the necessary research and development to new underground mining methods and insist on reclamation as an integral part of strip mining, there is every reason to believe that our vast coal resources can be extracted from the earth in a safe and efficient manner without destroying the land.

There remains a major hurdle in converting coal into a convenient and clean form. Here, too, the job can be done if the necessary research and development is undertaken on an intensive enough basis.

In the final analysis, the future of coal lies with the scientists and engineers whose task it is to develop the hardware to mine and burn coal economically and with minimum damage to people and to the environment. The problem is to put more of our best scientists and engineers to work on the problems and this happens only when more R&D efforts are well planned and funded. I can assure you that our Office will be exerting every effort to see that the federal government increases its efforts toward these ends and carries out its fair share of the job. But the impetus must also come from the coal industry, from the utilities (both publicly and privately owned), and from interested agencies of government at the state and regional level.

This Symposium presents a unique opportunity to mobilize the many entities interested in a regional resource to take actions that will benefit the nation. If I can sound a keynote for your Symposium, it is to concentrate on the follow-up actions that we can take as government officials, utility executives, university professors, equipment manufacturers, conservationists, or just interested citizens. As we listen to the ideas and discussions in the next two days, let us continually ask ourselves the question: "What can I do to help meet the future energy needs of the nation with minimum damage to the environment?" If we ask the question often enough and take follow-up action on the answers

we develop, I feel confident that we can meet energy needs and environmental concerns and that Montana coal can play a useful role toward that end.

COAL EXPORT BY WIRE

Ken Holum

Governor Anderson and the Montana delegation deserve high compliments for planning and organizing this Symposium. I am confident that we will have a useful and exciting two days in Billings.

During the next two days, attention will be focused on a Montana resource that has been under-utilized. The Symposium will consider opportunities for utilizing Montana's coal to strengthen the economy of the State by providing additional job opportunities in Montana. Simultaneously and appropriately, attention will be focused on the need and the opportunities for protecting the environment while utilizing the coal. This Symposium is certain to be good for Montana.

Many people, representing a wide variety of organizations and commercial interests, have come to Billings to attend and participate in this Conference. We have come because we recognize that Montana coal has the potential ability to provide a greater portion of the nation's energy requirements at lower cost to the economic benefit of our home state or region. If this proves to be the case, the Symposium may well be identified as an occasion that led to new higher levels of economic activity in Montana and the whole West.

Personally, I am not surprised to find your congressional delegation sponsoring and organizing activity designed to focus West-wide attention on Montana coal. During the eight years that I worked for our national government in the water and power arena, your Senators made certain that I never overlooked Montana coal as a potential resource of great importance to the electric power industry. This was especially true when we were investigating the feasibility of transmission line construction and particularly true when we considered the possibility of extra- and ultra-high voltage transmission interconnections between the Pacific Northwest and the Missouri Basin area.

Ultimately, the studies and investigations that were conducted by the Department during that period led to the preparation, publication and distribution of a document entitled Study 190. Study 190 conspicuously and appropriately makes certain that all of the possible transmission line configurations cross the coal fields that we will be discussing here in Billings today and tomorrow.

I am here this morning at the invitation of Governor Anderson and your Congressional delegation to discuss the subject "Coal Exports by Wire." Study 190 inevitably becomes the "take-off point" for any discussion of that subject.

A little less than nine years ago a new administration assumed responsibility in the Department of Interior. In retrospect it is is really amazing to recall how quickly that new team agreed

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Ken Holum, former Assistant Secretary of the Interior for Water and Power

that interconnecting the Federal power systems of the West and helping to advance the technology of high-voltage transmission of electric power was to be one of its principal goals.

Certainly it must be significant that on February 23, 1961, (one month and two days after assuming office) President Kennedy said in his precedent-setting message to Congress on natural resources, "I have directed the Secretary of the Interior to develop plans for the early interconnecting of areas served by that Department's marketing agencies with adequate common carrier transmission lines ....."

I could attempt to reconstruct for you the whole sequence of investigations, discussions and negotiations that led eventually to decisions approved and funded, to construct the West Coast inter-tie with its high-voltage A.C. and D.C. facilities. It will be sufficient, I believe, to state that ultimately everybody involved agreed that the proposed network was technically feasible and that its construction would provide economic benefits to the whole West and all the utilities operating in the region. Simultaneously, fabrications of the equipment and construction and operation of the facilities substantially advanced American technology in the field of high-voltage power transmission.

Eventually, the experience gained in planning the West Coast inter-tie and the continuing study of possible interconnection between regions led Interior's power marketing agencies to the conclusion that one consolidated long-range planning study for the entire West would be the most logical approach. Study 190 is the end product of that conclusion, and the study which followed.

The study effort conducted by dedicated and highly competent technical personnel from the Bonneville Power Administration, the Bureau of Reclamation, and the Southwest Power Administration, eventually focused on 12 different transmission schemes designed to interconnect the entire region from Chicago, St. Louis, and Dallas in the East to the Pacific. The group found that all schemes would operate satisfactorily under both normal and emergency operating conditions. Assuming Federal cost ratios in effect at the time (3.25% interest and a 50 year payout), all 12 schemes had favorable benefit-cost ratios.

Planning and building the 1100-mile West Coast inter-tie, together with the information made available by Study 190, makes it possible for us to say categorically and emphatically as we examine the subject "Coal Export by Wire" that it is technically feasible to deliver energy from the coal fields near Billings, Montana, to Chicago, St. Louis, and Seattle over the high-voltage electric lines. Actually, the coal fields of Montana and Wyoming and the lignite fields of North and South Dakota are strategically located almost at midpoint on the Study 190 transmission systems.

Technical feasibility is important. However, I am sure that even the most avid advocate of utilizing Montana coal and constructing a West-wide transmission network would not wish to proceed unless we can be confident that doing so is financially feasible as well and that the system can be expected to contribute to keeping the cost of electric energy at the lowest possible level.

As noted earlier, Interior's competent study team found all of the networks they analyzed to be financially attractive at then applicable Federal costs. Interior released the report and distributed it to the electric utility industry "hoping the document would encourage all segments of the electric industry to proceed with cooperative planning."

It may be that Interior failed to make its position clear at the time the report was released. If that is true, I must assume complete responsibility. In any event, instead of initiating cooperative planning, a large segment of the power industry has dedicated time and energy in what appears to have been an effort to discredit Study 190 and particularly its financial analysis. Using a different and more conservative set of criteria, they have found that costs exceeded benefits by a narrow margin.

If it were important to the Symposium or to the long-range potential use of Rocky Mountain coal to serve West-wide power requirements, we could discuss the relative merits of the criteria used in the two studies. We will not do so because the question has no relevance. The important question is how do you meet the West's growing electric power requirements at the lowest possible cost.

Study 190 is an analysis of a transmission system. No one questions its technical feasibility. Everyone agrees that interconnecting large electric systems produces savings. Additional savings occur when the systems have different climatic conditions and operate in different time zones.

Now that we know that it is technically feasible to interconnect the West with a high-voltage transmission network, and now that we have agreed that building the transmission system will by itself create savings that will amortize either all or a large portion of the cost, we must determine whether or not Rocky Mountain coal burned at or near mine-mouth, can produce electric energy at costs low enough to be competitive when delivered to distant load centers over that type transmission network.

During the last 10 years, we have observed that improved technology and high-voltage transmission has steadily enlarged the area served by mine-mouth plants located in West Virginia and Pennsylvania. Coal is moving by wire from Four Corners, New Mexico, to Los Angeles and San Diego. TVA is making diversity exchanges with power systems in Texas, Oklahoma, and Illinois.

It is the growth in power loads, generally doubling every 10 or 12 years, together with improved transmission technology, which makes possible the development of distant sources of fuel. Mine-mouth plants in West Virginia and Pennsylvania became feasible when 500-kv transmission became a reality. North Dakota lignite began to be utilized on a large scale when the rural and municipal loads grew to the point requiring a 200-mv unit in addition to the Federal hydro power supply. The feasibility of using Rocky Mountain coal in large quantities relates to the loads of the 70's of the systems covering a wide area of the West and the availability of the necessary high-voltage transmission line technology.

Two possibilities exist for substantial increases in the amount of Rocky Mountain coal that moves to the ultimate energy

user by electric conductor. (1) a utility, or a group of utilities in a region, may find that min-mouth power generation in the Mountain States constitutes the cheapest and most acceptable source of electric energy for all or a portion of their future requirements, or, (2) Groups of utilities in different regions may find that major generating stations centrally located in the Rocky Mountain area are financially attractive, because they can capitalize on the economic benefits, inherent in inter-regional power exchanges, as well as the cheap fuel.

Electric loads are growing rapidly in markets east, west, and south of the Rocky Mountain area. Although the major load centers are several hundreds of miles from the coal fields, high-voltage transmission places Seattle-Portland, San Francisco, the Twin Cities, and even Chicago, together with all of the intervening utilities, within the potential market area. We must understand, however, that the economic feasibility of using Rocky Mountain coal, delivered by wire, to serve these large and growing loads requires that we achieve the economies and efficiencies inherent in large generating stations and high-voltage transmission lines.

It may be that a single large utility may at some time find itself in a position where its own load growth will justify the construction of facilities large enough to make mine-mouth generation in the Rocky Mountain region economically attractive. It is much more likely, however, that the coal resourses we are discussing here in Billings will become attractive to regional groups where utilities of all types are working together to achieve low-cost power supply for all customers. The hydro-thermal accord in the Pacific Northwest, and the joint planning being done by the West group in the Pacific Southwest provide logical beginning points for this type of an effort.

Montana citizens who look optimistically to the development of the State's substantial coal resources to provide new levels of economic activity in Montana must understand that utility managers will be guided principally by economic evaluation. At the same time, as the public becomes increasingly concerned about both costs and environmental factors, utility managers are finding that they must evaluate all alternatives before making decisions. If they expect those decisions to receive public acceptance and approval.

Although it would be premature and unwise to predict the results before the studies are made, I am convinced that Rocky Mountain coal deserves careful economic evaluation before any region west of the Mississippi commits all of its future power requirements to nuclear reactors.

The strong trend to nuclear reactors that existed a few years ago has been substantially modified. At that time, difference in initial investment costs between nuclear and fossil units was insignificant. Now nuclear units are costing at least one-third more than fossil units of the same size at the same location. Ordinarily, lower fuel costs for nuclear plants help to offset the higher capital costs. However, Rocky Mountain coal may well produce fuel costs that compare favorably with the cost of nuclear fuels. These factors, together with a wide variety of environmental matters that must be considered in siting plants, regardless of the fuel utilized, makes it essential that detailed comparisons be made of the available alternatives.

Although I see a real possibility that large generating plants located at mine-mouth and feeding power over high-voltage transmission lines in one direction may be economically attractive. I am confident that inter-regional planning by electric utilities will demonstrate that the savings can be substantially increased if transmission lines are planned and built so that the power can be delivered east or west or south as the demand requires.

Study 190 has established that either all or a large share of the costs of a transmission network can be amortized by the savings that you achieve by building the network. Although a definitive analysis needs to be made in such case, it is obvious that large generating stations located at or near midpoint on such a network are certain to increase reliability and reduce costs. Such plants would provide increased flexibility in displacing power deliveries, so that exchanges between distant systems can be effectuated by modification of the east and west deliveries of the mid-point plants. With modern mining techniques, it seems almost certain that the cheapest, large-scale reserves of fuel in the country are located in Montana, Wyoming, and the Dakotas.

Although specific plant locations, transmission line layouts and the extent of participation in ownership should not be determined until careful and detailed studies have been completed, I am certain that mine-mouth plants in the Rocky Mountain region and high-voltage transmission lines that interconnect regions, constitute the cheapest source of bulk power supply for a large share of the West's energy requirements.

The important question facing electric utilities today, as I stated earlier, is how to meet growing supply requirements at low cost, while maintaining high standards of reliability. Final long term decisions should not be made before all alternatives have been studied and evaluated. I am convinced on the basis of preliminary investigation that cooperative studies will almost certainly establish large mine-mouth generating plants in Montana and Wyoming and extra-high-voltage transmission lines as the best way of supplying a substantial portion of the West's future power requirements.

COAL EXPORT BY RAIL
(INTRODUCTION OF E.F. MC GUIRE)

John F. Mc Grath

Minnesota Power & Light Company was pleased to take part in the expanded development of Montana coal reserves and is proud to have been invited here to participate in this meeting devoted to study of this natural resource which has such great potential value. When I was asked to appear and discuss the export of coal by rail, I was flattered and immediately accepted but suggested that someone other than a lawyer would be better informed on the subject.

Elwood F. McGuire, known to all as Mac, has been the key man of this project since before I ever joined the Company. Accordingly, we decided that he was the one to discuss this topic with you. As you may or may not be aware, there is sometimes a little professional jealousy between engineers and lawyers and Mac has a favorite story he likes to needle me with.

In view of this high regard he has for lawyers -- particularly when they are asked to hold forth on a technical subject such as this, I felt that it would behoove me to step aside and turn the topic over to him. This was conditioned of course on his agreeing to allow one to accompanying him to this meeting and on a visit to the mine which he named the Big Sky mine.

Mac has a long history in the Electrical Industry although he came into it with an educational background which, like my own, would not normally lead to such an affiliation. He is an aeronautical engineering graduate of Purdue University. He was a naval officer in World War II and after discharge became affiliated with Combustion Engineering Company. Here he fell in love with boilers and spent five years in charge of starting up operations of large boiler installations around the country, particularly for utilities. He became very interested in all phases of their operations but particularly those relating to fuels. After joining MP&L in 1952, he has spent most of his time, after helping erect our new plant in 1958, with improvement of our existing facilities. He is now in charge of constructing our new 350,000 kw plant at Cohasset, Minnesota, which is due for commercial operation in May, 1973.

Before turning this over to Mac, I want to say that we believe Montana coal is the answer to our fuel problems at least for the immediate future. As you will hear, this decision was not lightly made. The years of searching, comparing, testing, and setting up transportation we believe will permit us to remain a viable utility entity. We are proud of what we think were pioneering efforts and we will be pleased to share with others the results achieved.

Now I can't think of a more knowledgeable person to discuss with you the export of coal by train and the history behind MP&L's use of Montana Coal than E. F. McGuire.

John F. McGrath, Vice President, Minnesota Power and Light, Duluth, Minnesota

COAL EXPORT BY RAIL FROM MONTANA TO MINNESOTA

Elwood F. McGuire

As Jack McGrath has indicated to you, our Company has studied for many years a new large unit on our system which could serve our area on a competitive basis. This is now a reality and we will be adding a new unit rated at 350 MW to our Clay Boswell SE Station. It is expected that this plant will burn between 2 and 3 million tons of Colstrip, Montana coal annually.

This is an artist's conception of the Clay Boswell Steam Electric Station when it is completed in 1973. It dramatically illustrates the size of our new unit when compared with the two existing units. These are our next two largest generating units and this unit addition will almost double our present steam generating capacity.

Our Company is a smaller electric utility serving the Northeastern portion of Minnesota with principal load centers on the Mesabi Iron Range and in the Duluth area. While we do have 105 megawatts of hydro-electric capacity located principally on the St. Louis River, this energy source has been almost fully developed for many years. Subsequent expansion has been by use of fossil fired steam electric stations. Our present steam electric stations in addition to the Boswell plant located at Cohasset on the west end of the Mesabi with a capacity of 140 megawatts, are the ML Hibbard Station located in Duluth with a capacity of 125 megawatts and the Aurora Station located at Aurora on the east end of the Mesabi with a capacity of 116 megawatts. We also have 25 MW installed capacity at our subsidiary Superior Water Light & Power Company. Total installed system capacity is 511 MW.

All of these steam generating plants have traditionally burned eastern coal primarily, and all units are pulverized coal fired. The eastern coal has generally originated in Southwestern Ohio, Northern Pennsylvania, Northern West Virginia or Eastern Kentucky. It is shipped via rail to a port on Lake Erie, then loaded into a lake vessel, transported to Duluth and Superior, removed from the vessel and stored on the Duluth-Superior coal docks and shipped to the stations by rail as needed on a daily consignment basis. Since there are a number of much larger utilities between us and the supply source, competitive freight rates have been a larger problem than coal cost at the mine mouth. This has placed us in a very high fuel cost area with these costs ranging from 34 to 43 cents per million Btu's.

Since our principal load has been the iron mining industry and subsequently the taconite industry, our high fuel cost has hindered sale of electricity to this industry. In fact two of the six large taconite companies have installed their own generating capacity in the mid 50's with added capacity since that time.

In 1962, we became an interconnected member of the Upper

Elwood F. McGuire, Manager of Plant Engineering, Minnesota Power and Light, Duluth, Minnesota.

Mississippi Power Pool which now consists of Cooparative Power Association, Dairyland Power Cooperative, Interstate Power Company, Lake Superior District Power, Northern States Power Company, Rural Cooperative Power Association, Minnkota Power Cooperative, Montana Dakota Utilities Company, Northern Minnesota Power Association, Northwestern Public Service Company and Otter Tail Power Company. Most of these companies have lower fuel costs.

In 1963, the Department of the Interior reported that our fuel costs were well above both the average of plants throughout the United States and the average costs of other plants operating in Minnesota. At the time our service area was considered to be a depressed area by the Federal Government. It became imperative that if we were to survive as a generating electric utility, lower cost fuel would have to be obtained.

We obtained the services of a consultant who made a study of integral train movements of coal to us from such diverse places as Eastern Kentucky, Southern Indiana and Southern Wyoming. We also investigated possibilities of a train hauling coal to us with a return load of taconite pellets to the steel mills in the coal producing areas.

Our problems with high cost Eastern coal are most dramatically illustrated by the fact that in 1959 we burned 496,000 tons of coal which represented 99% of our energy requirements. In 1968 our actual fuel requirements were 1,150,000 tons; however, we burned only 596,000 tons of Eastern coal. The other 554,000 tons were displaced by cheaper energy.

In 1965, the Great Northern Railway came to us and stated that they were very interested in establishing a large volume lignite movement into Northern Minnesota. It was their belief that lignite could also be used by the iron mining companies for purposes other than generation of electricity. Using rates proposed by the Great Northern and coal costs proposed by a coal company, we began to seriously study the use of lignites from both North Dakota and Eastern Montana. At the same time, we were studying the addition of a nuclear unit to our system.

At about this same time Northern States Power Company decided to locate a plant north of Minneapolis on the Mississippi River at Monticello. This was to be in the 550 MW range. The fuel evaluation was between North Dakota lignite and nuclear. In this particular instance, nuclear proved to be the most economic, however the unit train rate quoted was a clear cut demonstration by the Northern rail lines that they were willing to make attractive rates for lignite when moved in unit train volumes. These proposed freight rates allowed us to consider the lower rank fuels available in abundance from Western locations.

It soon became apparent to us that a computer evaluation involving our entire system which would include all our plants, taxes, transmission line costs, all fuel costs, purchased power, capital costs of a new unit and other factors would have to be developed. This program, although somewhat rudimentary proved to us that a lignite fired unit could be installed at our Clay Boswell Station and would be competitive with a nuclear unit. Several locations and sizes for nuclear and fossil fired units were studied. We then obtained the assistance of Nuclear Utility Services known as NUS of Washington, D.C. to refine the computer

program and to provide us with more accurate cost data. From this it was determined that we could proceed with either a lignite fired unit at the Clay Boswell Station or a nuclear unit somewhere else on our system.

Our previous study of unit trains had taught us that a total system approach was necessary. This total system approach included the coal reserves, the coal mining companies, the railroads, the unit train unloading facility, the steam generating unit and the turbine generator unit. To advise us on the coal reserves and the coal mining companies, the Paul Weir Company of Chicago was retained in April, 1967. They were involved with all our subsequent negotiations with coal companies and their abilities have proved invaluable to us. In July, 1967, we gave General Electric Company a letter of intent to purchase a turbine generator which was to be either nuclear or fossil and was to be placed in service in early 1973. At that point in time it was believed a nuclear unit required a five year lead time.

Concurrently a large coal company approached us at about this time concerning sub-bitumious coal from an undisclosed location in Montana. Shortly thereafter a second large coal company also approached us on the use of sub-bituminous coal. It turned out that both companies were offering coal from Colstrip, Montana.

With the help of the Paul Weir Company, a General Specification was developed. This specification included a schedule of tonnages, desired contract provisions, coal reserve requirements, test coal requirements, proposed Btu guarantees, projected coal analyses and several other provisions. Most importantly, proposed tariff provisions were to be incorporated in the replies. This specification was sent to eight potential suppliers which could supply either lignite or sub-bituminous coal from Burke County, North Dakota; Mercer County, North Dakota; Burns Creek, Montana; or Colstrip, Montana.

Knowing the delivered cost in cents per million Btu and the proposed coal analysis, we were now able to make a complete evaluation using our previously developed computer program. We could evaluate the differences between lignite and sub-bituminous and compare both with nuclear.

The successful bidder, Peabody Coal Company, supplying sub-bituminous coal from Colstrip, Montana was then given a letter of intent subject to the obtaining of a reasonable approved rail tariff based upon their help with final negotiations with the railroads. Since it was to be a combined Northern Pacific-Great Northern haul, we should emphasize that the haul had been approached by them as a single line haul. The economics inherent from this approach were therefore made available to us. After receiving a tariff proposal that seemed reasonable from the Great Northern and the Northern Pacific, a twenty year contract beginning in 1973 was signed providing the tariff could be filed with the Interstate Commerce Commission. This contract with Peabody also provided for shipment of coal to our other existing plants starting on May 1, 1969. It was our intent to convert all our units to sub-bituminous. The rate as published, which meant considerable fuel savings before 1973 as well as after was suspended by the Interstate Commerce Commission on December 3, 1968, primarily as a result of objections by the Eastern Railroads. It was subsequently reissued in different form applicable to our

Clay Boswell SE Station only and thus excluding our other plants and our total system approach.

In May 1969, we started receiving the first sub-bituminous coal via unit train at our Clay Boswell Station. Each train is made up of 100 hopper-bottom cars each containing about 104 tons. This train makes a round trip about every six days and to date we have received 24 trains. It is anticipated that between 650,000 and 700,000 tons will be received annually for burn in our existing units at Clay Boswell Station.

These units were converted over to sub-bituminous by July 1, 1969, and western coal has been burned since that date. The two units at this station are rated at 70 MW each and they operate at 1450 psig and 1000 F/1000 F. Conversion consisted mainly of additional pulverizing capacity, additional forced and induced draft fan capacity, additional burner capacity and increased the number of soot blowers.

Problems have been encountered with steam temperature and exit gas temperature. Ash characteristics have been excellent. For the most part coal has handled very well. The most gratifying part of the operation has been that every train has operated on schedule projected by the railroads.

Our new unit at the Clay Boswell Station will be a 350 MW unit operating at 2400 psig and 1000 F/1000 F. This is a side view of our new steam generating unit which was purchased for a cost in excess of $10,000,000 from Combustion Engineering in July, 1969. It is to have five Raymond bowl type pulverizers capable of pulverizing 50 tons of coal per hour. Probably the most significant feature of the unit which will produce 2,500,000 pounds of steam per hour is its designed exit gas temperature.

It was found after some investigation that the unit should be designed for low exit gas temperature. Montana coal delivered to us is very low in sulfur content. Until now the industry has used electrostatic precipitators to meet low particulate emission requirements. Flyash from low sulfur coals is difficult to collect in a temperature range from approximately 285 F to 580 F in these precipitators. The manufacturer has guaranteed an exit gas temperature of 260 F, which is below the trouble range. This means than an efficiency gain is possible along with a reduced cost for an electrostatic precipitator.

Thermal effects are also a major component in our environmental studies. The Clay Boswell Station is located between two lakes which are connected by the Mississippi River. The new unit is to be equipped with cooling equipment on a closed cycle basis and will have no thermal discharge.

In full operation, with three units, between 2 and 3 million tons of coal will be burned annually. This coal is to be received in railroad owned gondola type cars equipped with swivel couplings. Each car is to carry about 105 tons and each train is to contain a minimum of 10,000 tons. A loop track capable of holding at least 120 cars plus the five locomotives in a continuous string is to be constructed at the plant. The train is to be indexed automatically through a rotary car dumper. Unloading rate as presently projected will be at 3000 tons per hour. Five trains per week will be required and expected turnaround time for

each train is 72 hours. It is anticipated that delivered cost of this Montana coal in 1973 will be very close to the national average and will also enhance our competitive position in comparison with our neighboring utilities.

When projected growth of the electric utility industry is studied, it will be recognized that all forms of energy source will be needed. Depending upon the size and location of a given utility, it will be recognized that nuclear units will be needed, mine mouth plants with ERV will be needed and coal fired units located near load centers served by railroads will be needed. We think that Montana coal delivered by rail is our solution for the near future.

Other utilities are also experiencing difficulties with lake-borne Eastern coal and we would expect that these markets could be developed for Montana coal. When the low sulfur content and good ash characteristics of this coal are also considered, additional markets should be available. It is conceivable that this coal can be moved down the Great Lakes. When the capital costs of generating units, their availibility, air pollution, cost of mining and the costs of shipping through densely populated areas are considered, it can be said that the future of sub-bituminous is indeed bright.

A NATIONAL POWER GRID
(Luncheon Address)

William E. Warne

The experience of the United States has been for decades that increasing power demands of our industralizing society have required with the passage of each ten year period the doubling of the electric generating capacity. In the Northeast and some confined markets, such as the New York City and Westchester County service areas of Consolidated Edison Company, the projections are that this rate of increase may slow down to one which will require doubling the generating capacity in twelve years rather than ten in the future, but the prediction for the nation as a whole is for a doubling with each decade to the end of this century. One Kw new by 1980 for each Kw installed today; three Kw new by 1990 for each Kw installed today; seven Kw new in 2000 for each Kw installed today. The magnitude of the task of meeting these demands is almost enough to boggle the mind.

The problem encountered by the utilities in rapid expansion of their generating capacities are complicated by manufacturing problems -- the larger and larger units require newer and newer fabrication facilities and techniques; by financing problems, to duplicate billions of dollars of investments in electric generators will cost billions of dollars and more and then there is the cost of replacing the obsolescent plants in the present generating batteries, plants that are 40 or 50 years old and are inefficient and subject to unexpected breakdowns; by technical problems such as those connected with design, construction and safe operation of nuclear powered units and system balance and pool operations among interconnected systems; and an emerging problem of siting of new power plants.

This last named problem grows out of an increasing concern for the American environment as megalopolises form from Washington to Boston along the East Coast; from San Diego to Santa Barbara in California; around southern Lake Michigan and elsewhere. In such areas, there are not now, and are not going to be later, places for twice as many power plants by 1980 or seven times as many by 2000, which is only 30 years away.

What we have been doing these last several decades is building within the areas served by utilities. This is no longer good enough.

The Consolidated Edison, for example, is finding its planning for the next ten years complicated by the fact that there are too few sites for new power plants within the area it serves. New York City simply cannot accomodate in its environs a multiplication of generating stations.

The National Coal Policy Conference, Inc., of Washington, D.C., in its October 9, 1969 newsletter said that there is a dramatic

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expansion of coal-generated power in the west and it lists some very large projects now under construction and being planned, none in Montana, however. The influences that are bringing these developments at Four Corners and elsewhere are going to be felt in other areas soon.

Let me review from a report recently made on New York's power supply by a thoughtful group which reviewed the problem. Here is a part of what they said:

> As we see it, the power industry of the United States is moving toward the future of large integrate transmission networks, supplied with power and energy from very large, efficient power plants, located where they should be from the point of view of power system economy and efficiency. Systems will continue to own their own facilities, but will share with others the benefits and costs of the integrated networks and related power resources.
>
> This is a recent trend, although not a new concept. There are significant examples in the West. The Four Corners Plant, with several owners, located where Colorado, Utah, New Mexico, and Arizona meet, was sited at an economical source of coal and the power is transmitted as far as California. The Northwest and the Southwest have been interconnected at extra high voltage to secure the advantages of integated operation. The list is lengthening.
>
> The recent report (November 1968) of the Northeast Advisory Committee to the Federal Power Commission included the vision of a 765 kv network, to be developed in the decade of the 80's, linking the power systems of the Northeast region with nuclear and conventional power plants feeding their output into the transmission network.
>
> This development will mean that reliability and economy of power supply will increasingly be a regional concern as well as a local concern. The power agencies will need to evolve a set of relationships which will provide the institutional underpinning for the regional power system of the future.
>
> In order to produce the atomic bomb, a Manhattan District was organized and two billion dollars expended. In order to reach the moon, a special organization with vast sums at its disposal did the impossible. If we believe that the future of cities ten years hence, or twenty years hence, their livability, depends upon new methods of supplying electricity, then the record of the last twenty years of American achievement fortifies the belief that this can be done. The only question is when do we wake up to the fact that this is essential for the future of urban life, and when do we give this objective the kind of intellectual excitement that will draw into the electric field the innovative, daring young minds that have in the past drifted away from the electric industry into other fields.

How does this affect Montana? This morning David S. Freeman, Director, Energy Policy Staff, Office of Science and Technology, Executive Office of the President, gave the answer. He said there are 14 billion tons of coal of low sulphur content in Eastern Montana that it is known now can be efficiently strip-mined. This coal, which is only part of the reserves in that area, is greater as an energy reserve than all of the proved reserves of natural gas in the United States.

Mr. Kenneth Holum also speaking at this symposium this morning said:

> Two possibilities exist for substantial increases in the amount of Rocky Mountain coal that moves to the ultimate energy user by electric conductor. (1) a utility, or a group of utilities in a region, may find that mine-mouth power generation in the Mountain States constitutes the cheapest and most acceptable source of electric energy for all or a portion of their future requirements, or, (2) Groups of utilities in different regions may find that major generating stations centrally located in the Rocky Mountain area are financially attractive, because they can capitalize on the economic benefits, inherent in interregional power exchanges, as well as the cheap fuel.

I think Mr. Holum might well have said "will" rather than "may" with reference to his projections because the time is at hand for gigantic cooperative projects that will involve privately owned and publicly owned systems, the Federal government, the State governments and local communities. There are generation and transmission cooperatives now that serve several systems. The Pacific Northwest-Pacific Southwest intertie helped to establish the pattern for the future.

I look forward to establishment of a national power grid. It is not too soon to begin to plan it.

Montana must, it seems to me, become alert to its opportunities and prepare to meet them. I should hope that this symposium will lead to action both to further research that will hasten the day when the coal will be used and to protect the environment to avoid the social costs of exploitation.

If Montana does not become a participant, the state may well be victimized again as a scene of extractive industrial activity that will benefit the region only in minimal ways.

Congressman Holifield and Hosmer, Chairman and Ranking member of the Joint Committee on Atomic Energy, recently called upon the governor of California to form in the state an authority for the siting of power stations for the future. Big as California may be, they foresaw the need to avoid pre-emption of the limited number of power station sites for other purposes.

The time is at hand when Montana might well establish an executive commission responsible for both directing and controlling the use of the state's coal reserves.

The commission could establish environmental protective measures. It could review the allotment of the state's water in support of rational industrial development programs.

It could cooperate with Federal and industrial planners in laying out the interregional power generating and transmission programs that are to come.

It could provide the people of Eastern Montana and of the whole state with the assurance that their own aspirations are not ignored and that future development of their resources will help them into a better future.

PANEL: ELECTRIC ENERGY REQUIREMENTS IN THE WEST

Remarks of the Panel Moderator, H. G. Curtis

These distinguished panel members are here to discuss Electric Energy Requirements in the West.

This is a most pertinent subject for a coal symposium. Coal and electricity today are interdependent. More than half of all the electrical energy in this nation is produced from coal. And, conversely, electric generation provides more than half of all the existing market for the output of our coal mines. It would appear, therefore, that adequate electric power depends on coal ... and that a significant coal industry, must depend on electric generation.

This interdependence, traditional on a national scope, is somewhat new to the West. We, out here, have generated most of our electricity with falling water. Many of us had thought that, as we reached the limits of our hydro resources, the new nuclear power would fulfill our future needs. It has not turned out that way to date. And so today electrical industry in the American West, just as has that of the rest of the nation in the past, is looking at coal ... for at least a significant part of its electric generation of the foreseeable future.

These panelists will tell of our forthcoming electrical needs of the west. I believe their forecasts will show that there is a tremendous potential for Montana coal in fulfilling those power needs.

Henry G. Curtis, Executive Secretary, Northwest Public Power Association, Vancouver, Washington.

POWER POTENTIAL AND REQUIREMENTS OF THE NORTHWEST

R. B. Lisbakken

The power supply for the West Group of the Pacific Northwest Power Pool has traditionally and historically been based on the hydro generation of our river systems. Thermal generation, until recently has been relatively minor and has seldom been used, except on a standby or emergency basis, until the nuclear reactor plant at Hanford was completed in 1966.

The West Group portion of the Northwest Power Pool includes the states of Oregon, Washington, northern Idaho, western Montana, and northern California and has an installed capacity of about 20,000,000 kilowatts and thermal generation of approximately 500,000 kilowatts of oil and gas fired plants of relatively small size, plus the 800,000 kilowatt Hanford nuclear plant. Thus, the installed capacity in the West Group is 94 percent hydro and 6 percent thermal compared to the balance of the United States which has only 11 percent hydro capacity and 89 percent thermal capacity.

Adding British Columbia, Utah and southern Idaho to the West Group figures gives the total Northwest Power Pool area an installed capacity of about 26,000,000 kilowatts of which 91 percent is hydro capacity and 9 percent is thermal capacity.

The energy potential of our river system in terms of hydroelectric development is approaching its limit, although until the turn of the century there will be opportunities to develop additional hydro capacity by installing additional machines at existing projects and building pumped storage projects so that the hydro capacity will continue to be important to the economy in the growth of the Northwest. To meet the growing energy requirements of the area, we will be installing large blocks of thermally generated power, both coal-fired and nuclear, to meet the continually increasing demands for power and energy in the Pacific Northwest.

One hundred ten serving agencies of the region, including the generating utilities and the Bonneville Power Administration make up the Joint Power Planning Council, which has made a careful forecast of the capacity and energy requirements for the West Group of the Northwest Power Pool for the next 20 years. The Council includes 4 private utilities, 26 public utility districts, 33 municipal utilities, 46 cooperatives and the Bonneville Power Administration. Their forecast shows an expected growth rate of about 6 percent compounded per year, which indicates that the West Group area will require in excess of 60,000,000 kilowatts of capacity by 1990 compared to the present installed capacity of about 20,000,000 kilowatts. The Council estimates that roughly one-third of this capacity and one-half of the energy requirements to meet this 1990 load will be supplied from thermal generating plants with the balance to be provided by hydro plants.

Robert B. Lisbakken, Pacific Power and Light Company, Portland, Oregon.

To take care of the requirements during the next 10 years, the Joint Power Planning Council recently announced its plans to implement the Hydro-Thermal Power Program for the Pacific Northwest to plan the construction of 7 large coal and nuclear plants. The sponsorship and participation by both public and private utilities for the first four plants have been announced for 2,400,000 kilowatts of coal-fired thermal capacity and 2,100,000 kilowatts of nuclear capacity.

The investment in just these 7 plants, exclusive of transmission facilities, will approach 1.5 billion dollars. The 1,400,000 kilowatt coal-fired Centralia project in western Washington is now under construction for completion of the first unit in September 1971 and the second unit one-year later. It is jointly sponsored by Pacific Power & Light Company and The Washington Water Power Company with joint ownership participation by Puget Sound Power & Light Company, Portland General Electric Company, Snohomish and Grays Harbor P.U.D.'s and Seattle and Tacoma municipal systems.

The second thermal plant in the hydro-thermal program is the 1,100 megawatt Trojan nuclear plant being located near St. Helena, Oregon, sponsored by Portland General Electric Company with joint ownership participation by the Eugene Water and Electric Board and Pacific Power & Light Company.

The third plant is a 1,500,000 kilowatt coal-fired plant in southwestern Wyoming of which one unit will be owned by Idaho Power Company and two units by Pacific Power & Light Company.

The remaining 4,000,000 kilowatts of capacity is proposed as nuclear with sponsorship, participation and general location tentatively planned for location in western Oregon and Washington to complete the program through 1980.

According to a recent forecast of the Federal Power Commission, the total area of the Northwest Power Pool, excluding British Columbia, will require approximately 75,000,000 kilowatts of capacity by 1990 of which I would estimate that approximately 33,000,000 kilowatts will be supplied from thermally generated energy or 15 times that presently installed.

Since the completion of the Pacific Northwest-Pacific Southwest intertie lines and other high voltage transmission lines through Utah, Colorado and Arizona and the completion of large generating plants, such as Four Corners, the western states have become sufficiently interconnected so that large blocks of power are being interchanged and transmitted between areas to take advantage of seasonal diversities and economic energy sources in neighboring areas.

The utilities and Federal agencies in these western states have joined together in a planning and operating organizations known as the Western Systems Coordinating Council, which includes the Northwest Power Pool, Pacific Southwest Interconnected Systems, Rocky Mountain Power Pool and the New Mexico Power Pool. Geographically, the Council includes all of the states of Washington, Oregon, California, Nevada, Idaho, Utah, Colorado and Arizona and parts of the states of Montana, Wyoming, Nebraska, New Mexico and Texas.

Looking at the Federal Power Commission forecast for the Western Systems Coordinating Council area, we find that the Federal Power Commission forecasts an increase in requirements from the present 54,000,000 kilowatts of capacity to 218,000,000 kilowatts of capacity by 1990 which is a compound rate of growth of approximately 7.2 percent per year from the present. This means that the Western Systems Coordination Council area in the next 20 years will require nearly 160,000,000 kilowatts of additional generating capacity to meet the requirements for this expected growth. If we assume that the principal hydro capacity and pumped storage development over the next 20 years will be approximately 25,000,000 kilowatts, the remaining 135,000,000 kilowatts will have to be thermal.

The thermal energy to supply these western states' requirements can come from a number of sources: coal, oil, natural gas and nuclear. The particular fuel will, of course, depend upon the economics of the fuel sources to each area. There is no doubt that the large coal deposits in the Montana, Wyoming, Utah, Colorado and Arizona-New Mexico area will be a very important and major energy supply for these western states.

Whether it will be mine-mouth power plants with transmission lines to ship the energy, or unit trains to ship the coal to the plants, or oil-fired, natural gas or nuclear power plants, I'll leave it to other experts here today and tomorrow to suggest. I suspect we will use all methods and possibly some we haven't thought of before 1990 rolls around.

FUTURE ELECTRIC POWER REQUIREMENTS OF THE SOUTHWEST

R. J. McMullin

The Nation's power requirements have had a history of doubling every seven to ten years. The history of the Southwest is no exception -- in fact, it has exceeded the national trend during the past two decades. Between 1950 and 1960, population increased 39% compared with 19% for the nation as a whole. In addition, thousands of new industries located in the Pacific Southwest bringing with them more thousands of new supporting industries and services required to complement the economic activity of the region. With the increasing population and development of the West, there is every indication that its power requirements will continue to grow at the same rapid pace, if not even faster in the decade ahead. In fact, a study eompleted in 1964 by Stone and Webster, a nationally known consulting firm, indicated that by 1984 the growth of the region would require an additional 36 million kilowatts of generating capacity and involving an investment of over $5 billion.

To illustrate this growth and potential, let me describe what is happening in the area served by the members of an organization known as Western Energy Systems Transmission, Inc., popularly known as WEST. On September 22, 1964, the major electrical power suppliers in the Southwestern region of the country, comprising the areas of Southern California, Arizona, Southern Nevada, Western Colorado, New Mexico, Utah and West Texas, formed this organization for the purpose of jointly planning and developing the power resources of the area and to jointly plan transmission systems to carry the power to the load centers. The members of this group recognized that with the burgeoning power requirements and growth in population a joint effort was needed to assure that the needs were met in the most efficient manner possible, making maximum use of available resources, technology and managerial talents. The birth of this new organization marked a new era of cooperation among power suppliers in the Pacific Southwest. Obviously, the founding members believed in the concept of regional planning. Equally important, they recognized the need for a flexible and broad concept which could accomodate the various types of power suppliers in the region. The present membership of 12 investor owned companies, five municipal systems, three REA's, two irrigation districts, and one state power authority, indicates the extent of this spirit of cooperation and unity.

Specifically, this organization's participants engage in studies to determine: (1) area power requirements in megawatts, (2) area resources, such as natural gas, coal, nuclear energy and hydro availability, to meet these power requirements, (3) transmission systems to deliver the power and energy in the most efficient manner yet with the needed reliability so mandatory in this day and age, and (4) the design of power plants and transmission systems to most efficiently utilize the resources and right of way available.

Rod J. McMullin. General Manager, Salt River Project, Phoenix, Arizona.

Therefore, I believe that a review of some of the data generated by members of this organization will give a good overview of the future in the Southwest.

The 1969 loads of the members of WEST total 20,500 MW and 113.9 billion KWH per year. These requirements are projected to grow to about 35,000 MW and 197 billion KWH per year by 1976 and 46,800 MW and 265 billion KWH by 1980. In addition to the requirements of the participants of WEST there are, of course, other utilities in the area whose requirements must also be met. Overall, these studies indicate a growth rate of 9% compounded per year or a doubling every nine years.

Currently as of 1969 the participants' resources to meet these loads consist of 21,300 MW of thermal generating plants most of which are gas-fired but also included are some oil-fired, coal-fired and nuclear energy plants. In addition there are approximately 5000 MW of hydro and purchased power available from the companies own sources and by purchase from the USBR.

We find that members of WEST are planning new resources for the early seventies with 14,360 MW of capacity currently on the drawing boards or under construction within this area. Of this total 1,060 MW will be nuclear, 1000 MW hydro and 12,300 MW natural gas or coal-fired. Beyond this period there are already discussion proceeding for new capacity in the 1977-80 period. With construction now taking five years, planning must start very early.

Currently the largest practical size units being constructed are in the 750-850 MW range with 1000 MW units being utilized in some parts of the country. Units of this size represent a vast amount of new capital outlay, especially in today's market with its strong inflationary trend. Unlike some other industries, the power business cannot postpone adding capacity but must meeet the needs of the consuming public whether or not the period is inflationary. Therefore, to help offset these rising capital costs the industry must utilize the most efficient sized generating units and the least cost fuel.

The rising cost of natural gas as markets for higher use have expanded, the delay in economical development of nuclear energy plants and the high cost of oil have combined to put coal in a favorable position with regard to present and future fuel source. The development of large scale, highly efficient steam turbines and generators have aided this process. Large plants require huge amounts of fuel and when coal is required in such quantities the economies of scale associated with modern efficient mining operations can be effectively married to the economies of scale associated with large steam plants. Therefore, at present, coal is the leading future resource available to meet the near term requirements of the Southwest.

To give you an idea of the use WEST members are making of coal I will cite some of the present stations which utilize coal as a fuel. The first physical evidence of WEST planning was the 1.5 million KW addition to the three coal-fired power units owned and operated by Arizona Public Service Co. in the Four Corners area of Northwestern New Mexico. Six utilities, Arizona Public Service Co., Southern California Edison, Salt River Project, Public Service of New Mexico, Tucson Gas and Electric Co. and

El Paso Electric Co. are constructing two 755 MW units at this location. One unit is presently completed and another 755 MW will go on line in 1970 bringing the total to 2085 MW. There is sufficient coal and water to install another 2500 MW of capacity beyond the presently planned five units. When fully developed this site will utilize approximately 8 million tons of coal per year. Coal for the existing and expanded plant is supplied by Utah Mining and Construction Company from a strip mine at the plant site. Coal deposits of over 250 million tons are leased from the Navajo Tribe. The plant will cost about $150 million with another $30 million invested in the mine.

The Mohave plant, located in Southwest Nevada near Bullhead City, is currently under construction and will consist of two 750 MW units utilizing coal from the Black Mesa Mine in North Central Arizona. The participants in the Mohave plant include Southern California Edison Company, Los Angeles Department of Water and Power, Nevada Power Company and the Salt River Project. These two units are scheduled to go on line in 1970 and 1971 and will use approximately 5.7 million tons of coal per year. An unusual feature of this plant is the fact that coal for fuel will be transported 275 miles via a slurry pipeline from Black Mesa, Arizona. This will be the only slurry pipeline of its type operating in the United States, a shorter one having operated previously for a short period in Ohio. The coal will be mined by the Peabody Coal Company.

The Navajo Plant, which is just getting under way near Page, Arizona will consist of three 770 MW units with one unit scheduled for initial operation in each of the years 1974, 1975, and 1976. The participants in this plant include Arizona Public Service Co., Nevada Power Co., Los Angeles Department of Water and Power, the Salt River Project, and Tucson Gas and Electric Co. Included in the Salt River Project's share will be 560 MW for use by the United States Bureau of Reclamation to pump water for the Central Arizona Project. These units will also utilize Black Mesa Coal from Arizona and will use approximately 7-8 million tons per year. This coal will be transported via a unit train system on a 60 mile railway to be built from Black Mesa to the site near Page, Arizona. Peabody will expand the mine to handle both the Navajo and Mohave plants and their investment in developing this mine will be approximately $45 million. There are estimated reserves of 310 million tons of coal with another 90 million potential.

In southern Utah on the Kaiparowits plateau there is a coal field and sufficient water to support 5000 MW of steam generation. Several members of WEST have already begun preliminary studies of this Project with the tentative dates for installation of the first unit estimated to be completed about 1977. This proposed plant development will burn about 15 million tons of coal per year once all units are on the line.

In Western Colorado the Colorado-Ute REA Generation and Transmission Cooperation has a 167 MW plant near Hayden, Colorado which utilizes coal at the rate of nearly one million tons per year. This plant was constructed for Colo-Ute and the Salt River Project and there is sufficient coal and water for additional units. Current plans call for joint ventures to construct two or more units at or near this site. These units will probably be at least 500 MW each. When fully developed these plants will

utilize at least 4 million tons of coal per year. Peabody Coal Company also mines the coal used by this plant.

These, then, comprise the known future coal resources currently available to meet the load requirements in the Southwestern areas served by members of WEST. Altogether there is a potential use of approximately 40 million tons of coal per year by these plants generating 14,500 MW of the total capacity of 35,000 MW required. A substantial p tion of the remainder will probably utilize coal with nuclear plants as a definite possibility in the 1980's.

In the Southwest, as in other areas of the West, utilities are facing ever-increasing demands and also ever increasing problems in meeting these demands. First, as already mentioned, are the higher costs associated with inflation and a slow down in potential savings from economies of scale. Secondly, many of the participants, especially those in Southern California, are being subjected to environmental pressures. This latter is not unique to WEST membership, of course, as witness the troubles of Con-Edison in New York. Nor is it restricted to the environmental effects of air pollution from generating stations. Environmental effects such as siting (especially nuclear) unsightly transmission lines, thermal pollution, air pollution and ash disposal, including site reclamation, pose problems for the utilities as population pressures mount and aesthetic tastes change.

Coal can overcome some of these problems, at least temporarily because the coal beds are located remotely from load centers which helps solve two problems -- siting and air pollution. While being in remote areas does not remove the utilities' responsibilities in these areas, it does help to remove the pressures associated with these problems in population centers. Also, coal has provided a means offset higher costs and it is hoped it will not price itself out of the market as gas has done here in the West.

A problem of no small magnitude is the transmission system required to transport these huge blocks of power from remote areas to load centers with the reliability required to avoid disasters such as occurred in the Northeast in 1965. There still remains the problem of the very visible transmission lines which the whole industry, including the fuel suppliers, must overcome.

Thermal pollution is also a problem regardless of where the plant is located unless on the ocean and of course coal will always have the problem of ash disposal and coal site reclamation. Thus, while coal probably has a distinct advantage in meeting the future requirements for the reasons listed it also must help deal with the other environmental problems which are plaguing the electric industry and indirectly the coal industry.

In summary, we in the Southwest believe that coal has a strong future as a source of fuel for generating electricity. This belief is demonstrated by the fact that the major portion of new plants either being installed or planned for installation are to utilize coal as the basic fuel. We expect this to continue for all or most plants built through the 1970's. Perhaps nuclear energy will be economically feasible in the eighties, about the time when known coal resources commence to be scarce or not economical. I have attached a summary of the known coal reserves

within the Southwest area especially close to Arizona for your information. This summary indicates the estimated reserves, quality of coal, and where they are located.

General

Coal reserves within 200 miles of Four Corners are estimated at approximately 52 billion tons. Perhaps 25% of this amount would be of economic interest for our purposes, and approximately half of this amount would be recoverable. Usable amounts in this area, then, would total about 6½ billion tons.

Similar estimates for an area within 200 miles of Glen Canyon show this figure to be 7 billion tons, and within 100 miles of Glen Caynon, 1.4 billion tons. In equivalent steam generation, this last amount might support 1000 MW for some 250 years.

With the exception of a small amount of anthracite at Crested Butte (less than 1% of Colorado's aggregate coal resources), the area studied contains coal of bituminous and sub-bituminous rank. Approximately half of the reserves are within 1000 feet of the surface, the balance between 1000 and 3000 feet depth. Reserve estimates are based on a minimum bed thickness of 14 inches for bituminous and 3½ feet for sub-bituminous. Approximately 20% of the national production of coal is recovered by strip-mining, generally under 100 feet in depth. No estimates are made as to the amount of strippable coal in the Four Corners area; and, in fact, detailed analyses relating to this area are spotty.

Kolob Plateau

4,000 million tons (total), bituminous rank, minable thickness and quality particularly near Cedar City and to the Southeast. Accessibility good, particularly southeast portion.

Kaiparowits Plateau

3,000 million tons (total), bituminous rank, good thickness and quality, 20 to 25 miles north of Glen Canyon and on northeastern edge of field. Relatively remote, inaccessible and unexplored

Henry Mountains

200 million tons (total), part bituminous, part sub-bituminous in rank, relatively low in commercial value due to discontinuity of beds.

Black Mesa

4,000 million tons (total), some bituminous, predominately sub-bituminous in rank, thickness and quality fair to good in isolated outcroppings, less than fair over much of field, with best showings 60 miles north of Holbrook, 30 miles south of Monument Valley and 20 miles east of Tuba City. Considerable variance in estimates of reserves. Accessibility good.

San Juan Basin

Including the Zuni area, reserves probably exceed 40,000 million tons (total), both high sub-bituminous and low bituminous

in rank, irregular in distribution and quality except higher quality beds in Gallup-Zuni area and northern portion south to Farmington area. Accessibility generally good in New Mexico.

Pinedale

25 million tons (total), sub-bituminous, irregular thin distribution and low quality. Accessibility good.

Crested Butte

250 million tons (total), anthracite, semi-anthracite and bituminous rank, quality good but somewhat irregular in distribution. Accessibility generally good.

POWER REQUIREMENTS OF THE MISSOURI BASIN

F. G. Simonton

I am honored to be on the program of the Montana Coal Symposium.

I think it would have been better to have a representative of the Systems Group -- which is still the only regional planning and pooling group of consumer-owned utilities -- co-ops, municipals, and public power districts in the country -- as the spokesman on the subject of the electric energy requirements of the West -- especially since I am not an engineer -- but then, again, I can say that otherwise my morals are all right too.

Now, I always believe it is necessary to give a plug for the Association I represent -- Mid-West Electric Consumers Association. Some of you may not want to know about Mid-West or even electric power supply and our needs. It may be like the boy who asked, "Who invented soap?" His dad said, "Why don't you ask your mother?" And the boy replied, "I don't want to know that much about it."

But the membership of Mid-West Electric Consumers Association, located in the nine states of the Great Plains -- with wetlands to the East and the Rocky Mountains to the West, believe that joint action and joint planning enchances the ability of each of us to provide reliable electric service at the lowest possible cost -- low cost power is the key to needed economic development in the Great Plains.

Further, as an expression of philosophy, I am glad to see the emphasis on the environment in the content of this coal symposium -- because our members also believe in planning that supports and promotes wise resources management.

Genuine need, and a process of evolution, led us in the Missouri Basin to accept the idea of power supply planning on a regional basis. Time does not permit detailing of this now historic pattern, but the idea has resulted in the construction of a mine-mouth generating plant on the lignite fields of North Dakota. The idea has led to the maximum use of the existing transmission grid of the Bureau of Reclamation .. and the idea has led to Basin Electric Power Cooperative, and to the Ten Year Power Supply program. As you know that Ten Year Power Supply plan involves the Bureau of Reclamation with hydro peaking power; Consumers Public Power District with nuclear power -- and the first Basin unit -- and now a second unit at Basin -- a 400 megawatt lignite fired thermal power plant.

This power supply plan program assures our needs through 1975 ... but already steps must be taken -- in 1970 -- for the next phase of the regional power supply development. It was the lowly-lignite turned into electricity that prevented a shortage of the power in the 1960's and early 1970's. We believe the lowly lignite and coal of the west will again keep the light on and the

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Fred G. Simonton, Mid-West Electric Consumers Association, Denver, Colorado.

power supply adequate in the immediate future.

In the Missouri Basin we are going to have to more than duplicate the existing and planned hydro-thermal system we have today -- and do it by 1990. By 1985, the members of the Missouri Basin Systems Group will require the addition of 1.5 million kilowatts of new, efficient generating capacity, along with thousands of miles of high voltage, extra high voltage and even ultra-high voltage transmission lines. By 1990, the Joint System will require still an additional 1.5 million kilowatts of capacity. The major deficiencies in power supply occur in our area in 1977 ... particularly in Wyoming and Colorado.

Because we alone will need over three million kilowatts of capacity for the members and the associated high voltage, extra high voltage, and possibly even ultra-high voltage transmission, we have, in a real way, been investigating the coal resources in Wyoming, Colorado and Montana this year. We see the new technology -- the gifts of the scientists, engineers and manufacturers -- and the West Coast intertie with the proven A.C. and D.C. transmission as an opportunity for inter-regional planning -- joint planning and joint action to solve our power supply problem, and by so doing, keep electric rates for consumers low, and service reliable.

Accordingly, and in the tradition of consumer-owned groups who have always led the way for the low cost power and reliability of service, we called a meeting in Denver, in January of this year (1969) to keep alive STUDY #190, conducted by the Department of the Interior, and to set up the machinery for its refinement. On January 17, five regional associations of consumer-owned electric utilities met in Salt Lake City and formed a Task Force to promote further study and implementation of a west-wide extra-high voltage grid. It was our agreed intention to seek the participation of the appropriate Federal agencies and private companies, once our respective groups authorized their own participation. We did this because it was not only important to identify the locations where large fossil-fueled generating stations can be located ... but because we are convinced that STUDY #190 reveals clearly that a high voltage system design to take advantage of diverties of time, season, and climate, exist between the various systems of the West and was technically feasible and economically attractive.

While we in the Missouri Basin are moving toward the completion of the ten year power supply program, we also know that next year -- in 1970, we must really get down to business in the planning of the next generating unit which must be scheduled for 1977 commercial operations.

As concerned leaders of concerned electric utilities, we face new responsibilities if power costs are to be kept as low as possible, and if we are to maintain reliable electric service.

In the West, the Bureau, Bonneville, Salt River, Basin Electric -- and others are dependent upon Federal appropriations for construction. It seems reasonable that the long range plans of these agencies, should be aired before all interested parties.

It does seem vital that we begin talking in the West openly and frankly in order to build the foundations of inter-regional

relationships that can lead to cooperation in joint planning and joint action.

That machinery already exists -- with Mid-West, the Missouri Basin Systems Group, the Colorado River Basin Consumers Power-Northwest Public Power Association, Northwest Public Power Council, Southwestern Power Association, Bonneville, SPA Customers Group, the Bureau and others. We have it within our hands not to allow the new technology to master us or our environment. Instead, we have the opportunity to use technology to create the opportunities ... the great potential opportunities for human beings, not only in the West but in America.

I do not believe that our problem is technological nor even financial -- but it is political -- a conflict of philosophy, and of people. If we are to take advantage of inter-regional power supply planning, we must organize ourselves for bold and direct action that will raise in the public consciousness the issue of the need for economic development in the West, the need for joint planning. We must be the leaders to do something about pollution problems, and the environment -- about electric power rates and reliability. We must lead in the great effort to finally interlock the picture for economic growth in the west.

In summary, the growing need for power in the West, in my opinion, calls for long-range planning and real joint action by all of us if we are to have the facilities ready when needed. As Commissioner Michael Straus wrote a decade and half ago, "The ultimate proper utilization of our natural western resources for the benefit of the people can only be accomplished by coordinated, cooperative effort among all those responsible for providing such vital power needs."

That time has come for private power and particularly for public power, cooperatives, municipal and federal agencies, to lead on inter-regional planning and joint action. This is an idea whose time has come.

FUTURE PLANNING FOR POWER IN THE MISSOURI AREA

Neil L. Adams

Good afternoon, gentlemen. First, I wish to thank the sponsors of this symposium for inviting me out here to Montana to participate in this program. As the General Manager of Associated Electric Cooperative, I am directly involved in the production and transmission end of the power business for all the rural electric cooperatives in Missouri. Our annual power supply requirements at the present time are around three billion kilowatt-hours and are increasing at a rate well above the national average. One of the most important parts of our operation is looking to the future and planning for new sources of power supply. It is for this reason that I am most pleased to have the opportunity to participate in this symposium and learn something about Montana's vast reserves of coal which hopefully can be utilized to benefit the power supply operations in my part of the country.

I thought perhaps today you might like to hear something about how some of us view the power production fuel problems that we expect to encounter in our area of operation during the next five to ten years. At the present time, the major power plants operating in the central-midwest area -- north of Arkansas and east of Kansas -- are coal-fired plants. In Arkansas, Kansas and to the south, the major plants are, I believe, all gas-fired. In Missouri, we have looked primarily to the coal reserves in Missouri and Illinois as a source of fuel for the operation of our major power plants. Generally, the planning and programming for the additional amounts of power production needed to supply our projected power requirements is scheduled and firm through 1973. Within the next year we hope to firm up plans that will carry us through 1975. These plans include two new mine-mouth plants in Missouri that are now under construction by two of the private power companies operating in the state. These two new plants, together with two mine-mouth plants that are now in operation, will consume all of the known large coal reserves in Missouri. Two other major power plants now under construction in Missouri will burn Illinois coal. The cost of this coal, including transportation to the power plants, is about the same as the cost of mine-mouth coal in Missouri, which is around twenty cents per million Btu. Illinois coal has a little higher Btu content than Missouri, and the over-burden is less, resulting in a lower mining cost which just about offsets the cost of transportation, either by river barge or unit train. These two plants will have a maximum generating capacity of around two million kilowatts each and when fully loaded, each will burn around seven and one-half million tons of coal a year. With Missouri's coal reserves committed, we can now only look to Illinois for our future supply of coal. With new plants, each burning seven to ten million tons of coal a year, in my judgment, the power systems in our area need to start planning now for the day when Illinois coal becomes scarce. With the gas reserves for power production also becoming hard to come by in Missouri's neighboring states of Arkansas, Oklahoma and Kansas, we are interested in the huge deposits in

Neil L. Adams, Associated Electric Cooperative, Inc., Springfield, Missouri.

your part of the country.

In making our feasibility studies, we will be weighing the economics of bringing back this source of energy by rail or wire against nuclear fuel power plants constructed in our own area.

Missouri may seem far away to some of you, and I know that Montana seems far away to some of my folks. It is a shrinking world, however, and the huge demands for electric energy in our area and your huge reserves of coal out here may serve to bring us closer together. This may not be as far in the future as some may predict. I can cite one example that will serve to expedite this day. A new industry, an aluminum reduction plant, is being constructed next door to one of the new power plants that I mentioned was being built in Missouri. When all three phases of this new aluminum reduction plant are completed in about five years, it will utilize as much electric energy as all the rural electric cooperatives are presently utilizing in Missouri, or about three billion kilowatt-hours a year. I am sure other industrial expansion in the midwest will greatly increase our power supply requirements well above our normal load growth projections.

When I hear that the coal deposits in Montana and Wyoming have an over-burden of only ten to twenty feet and coal seams up to one hundred feet, compared to a seventy to ninety foot overburden and a three foot coal seam in Missouri, and coal that can be mined at a cost of eight to ten cents per million Btu compared to our twenty cents, I believe the prospects of us getting together are reasonably good. For it to become a reality is a huge task. For it to be feasible, huge amounts of power must be involved. This means a tremendous financing problem. Reliability will also be another key factor to be considered. If four to five thousand megawatts of power are to be moved to the midwest over seven to eight hundred miles of extra high voltage transmission lines, the interconnected power systems in our area must have the capability of responding to the loss of this supply. It also means great cooperation and working together of all segments of the electric power supply industry, which is probably the toughest problem of all.

I wish to once again express my thanks for being invited.

ELECTRIC ENERGY REQUIREMENTS IN NEBRASKA

D. W. Hill

It is difficult for a single individual or a single utility to speak with much authority about the power supply situation in the state of Nebraska. As most of you know, Nebraska is the only 100 percent public power state in the nation and, to date, has been probably the most difficult one for an outsider to understand. But, if I may digress just a moment, I would like to report what we feel is some significant progress in clarifying the power picture and bringing about a much more efficient operation.

A merger agreement has been signed, bringing together the properties of Loup River Public Power District, Platte Valley Public Power and Irrigation District, Nebraska Public Power System and Consumers Public Power District. We are confident this agreement will be implemented on January 1, 1970. The results will be that all of these properties will be merged into the Consumers' organization, except for the properties in the four-county area around Columbus. Loup will withdraw from the statewide wholesale operation of NPPS and will operate in this four-county area as a predominately retail utility. Loup will produce some of its power requirements from its two hydros near Columbus and will buy additional power needs from the new merged district.

Once the merger has taken place, the new utility will be known as the Nebraska Public Power District. The original board of directors will consist of the present seven-man Consumers' board plus seven from the Platte group. As terms of these directors expire, an eleven-man single board will be elected from 85 of Nebraska's 93 counties.

This new utility will be primarily responsible for providing power throughout Nebraska other than the area served by the Omaha Public Power District. There are other exceptions, such as some municipals who generate their own power or buy from the Bureau of Reclamation, and some REA co-ops in western Nebraska who buy their requirements from the Tri-State G&T of Denver, Colorado. So, in discussing the "Electric Energy Requirements in Nebraska", I will be talking about a combined total of all of these groups, some of which will provide their own power. Others will be looking to the new merged utility to assume this responsibility.

The annual net peak load and energy requirements projected for the years 1972 through 1990 are as follows:

Durwood W. Hill, Manager, Consumers Public Power District, Columbus, Nebraska.

YEAR	ANNUAL NET PEAK DEMAND (MW)	NET KWH (In Billions)	AVERAGE ANNUAL LOAD FACTOR (In %)
1972	2746	11.7	48.5
1973	2951	12.7	49.0
1974	3173	13.8	49.5
1975	3407	14.9	50.0
1976	3645	16.2	50.5
1977	3902	17.4	51.0
1978	4173	18.8	51.5
1979	4453	20.3	52.0
1980	4747	21.9	52.5
1981	5061	23.5	53.0
1982	5392	25.3	53.5
1983	5753	27.2	54.0
1984	6131	29.4	54.5
1985	6527	31.4	55.0
1986	6952	33.8	55.5
1987	7399	36.3	56.0
1988	7882	39.1	56.5
1989	8397	41.9	57.0
1990	8949	45.0	57.5

These projections are taken from a study made by the Nebraska Power Industry Committee, a group whose membership is made up of representatives of all the utilities throughout the state. These studies have proven in the past to be most accurate, and certainly most useful to everyone.

Now, a little bit about how Nebraska intends to meet these power requirements. Omaha Public Power has under construction at Fort Calhoun, Nebraska, a 470 MW nuclear plant now scheduled to come on the line in time for its summer peak in 1972. This new source, plus its existing generation and purchases, is estimated to take care of the Omaha District's needs through 1977.

Consumers District has under construction at Brownville, Nebraska, an 800 MW nuclear plant and it, too, is now scheduled to go into commercial operation in time to meet our summer peak of 1972. This plant, coupled with our present generation and purchase, plus an additional contract for 350 MW of seasonal power from the Bureau of Reclamation, is expected to carry us through the 1976-77 season.

1976-77 sounds like a long way off, but in planning new generating units this is a relatively short period. We have started an in-house study of our next unit and are looking at alternate sites and both nuclear and fossil units. In planning our Cooper Nuclear Station at Brownville, we acquired enough land to build four units the size of our present one, 800 MW. In designing Cooper Station, we have allowed for a second unit along side of the first one and we are confident that certain economies can be expected from the second unit, both in construction costs and in operating costs. However, we will make detailed studies of a fossil plant in outstate Nebraska, utilizing the more inexpensive coal from the western states; and, if studies prove that power from such an installation is more economical, we certainly will move in that direction. A plant, or a power source to the west of us, would provide another definitive incentive. That would be the transmission grid system that would necessarily be built in

order to import the large blocks of power. We need more interconnections to the west and northwest, and a unit in our western area would provide these ties. We feel that, in addition to some real low-cost power coming from our nuclear plant, the necessary Extra High Voltage transmission lines will prove to be almost as valuable in the future.

Existing state laws have certain restrictions regarding our utility's owning properties outside the state of Nebraska; however, we would look with favor on some type of joint venture that would take advantage of the low-cost coal of this region.

We appreciate having the opportunity of participating in these discussions and are looking forward to similar meetings in the future.

INTEGRATION OF HYDRO-THERMAL POWER SUPPLY

W. E. Trommershausen
and
R. B. Gallup

A. INTRODUCTION

In the past, many areas having adequate hydro resources undertook the development of such facilities. Typical areas such as New England. TVA, Bonneville, Missouri Basin, and Central California, were at one time almost wholly dependent on hydro power. Other areas were developed primarily on a thermal power supply base. As high-voltage transmission facilities were developed, it was possible to interconnect hydro and thermal generation to form effective power pooling operations. With the advent of the Northeast Blackout, the Nation's utilities have shown a greater interest in the use of hydro generation to support power pools that are based primarily on thermal generation. Furthermore, the Federal Power Commission (FPC) in its 1964 "National Power Survey" report (page 4) had this to say concerning future developments:

> "The Survey findings suggest that no longer need the availability of low-cost power be confined primarily to areas with low-cost hydro power or an economical fuel supply. Low-cost energy transportation is rapidly making all of the Nation's fuel and water power resources a common fund, economically available at great distances from their origin. The dramatic recent improvements in the cost of transportation of fuel by railroad and other modes, and in the transportation of energy itself through EHV transmission lines, will sharply reduce the differences in power costs among the various sections of our country."

As in all modern developments, there were many pioneers in the field of hydro-thermal integration programs. Attached is a map that was prepared more than 30 years ago by the late J. D. Ross, Superintendent of the Seattle City Lighting System and R. W. Beck, his assistant and the founder of the firm of R. W. Beck and Associates. These engineers predicted the use of DC transmission facilities to integrate the major hydro and thermal power areas of the United States.

The next major effort in this regard was a report that was prepared in 1952 by the Bureau of Reclamation under the supervision of Harvey McPhail, Assistant Commissioner of Reclamation. This report, which is now out of print, set forth some bold hydro-thermal integration concepts that have finally found their way back into Transmission Study No. 190. The following conclusion by Michael W. Straus, Commissioner of Reclamation, in the transmittal letter of the report, bearing the date October 28, 1952, is of special interest to those parties who are now fostering a sound hydro-thermal power program:

William E. Trommershausen, Chief Consulting Engineer, who presented the paper, and
R. B. Gallup (co-author), Principal Executive Engineer, R. W. Beck and Associates, Denver, Colorado, and Seattle, Washington.

"Estimates have been made for the future requirements of facilities to meet the needs of the next generation. Even though expressed in definite figures which are based on assumptions disclosed herein, these estimates at best can be taken only as an indication of the general trend. While the economic need of a high power transmission system and the general plan of such a transmission system are presented herein, the means by which such a transmission system might be provided is not considered. No doubt, elements of the system will be constructed by various power agencies operating in the area, both public and private. However, the ultimate proper utilization of our natural western resources for the benefit of the people can only be accomplished by coordinated, cooperative effort among all those responsible for providing such vital power needs.

The Bureau agrees with the view of the President's Materials Policy Commission that long-distance planning for maximum development of hydro resources supplemented by fuel resources, and for development of proper economical high-voltage transmission lines and interconnected systems, is a most important and immediate problem. Such initiation of sound long-distance programs should no longer be postponed to 'tomorrow'." (Underscoring supplied.)

In this paper we will discuss some specific experiences with hydro-thermal power programs that have been developed since 1952 and suggest some areas that merit further study by interested parties.

B. EXAMPLES OF HYDRO-THERMAL INTEGRATION IN THE MIDWEST

1. 1959 Power Allocation Report to Secretary of the Interior, Fred A. Seaton

In the process of making the 1959 hydro power allocations, Secretary of the Interior Seaton appointed a three-man committee consisting of Arthur V. Watkins (formerly U.S. Senator from Utah), J. Ruel Armstrong (Engineer), and Hatfield Chilson (Attorney) to make a report on the proposed hydro power allocation and "on the utilization of excess generating capacity in the marketing area". In the early days, the Bureau of Reclamation planned to sell as much load factor firm hydro power as possible and then sell the remainder as secondary and dump energy. In the mid-1950's the Bureau and the Corps of Engineers realized that some hydro peaking power could be used in the future with thermal generation. Accordingly, the installed capacity in the Big Bend Project in South Dakota, then being designed, was increased substantially to provide for a block of hydro peaking capacity. The Bureau then proceeded to allocate approximately 1,200 megawatts of load factor firm hydro power, with consideration of plans for hydro peaking power set for future consideration. The Seaton Report did, however, recognize the hydro-thermal integration concept, for it made the following statement:

"It should be borne in mind that the Missouri Basin Project Plan upon which the new allocation is based, together with Big Bend Dam (not yet started) substantially exhausts all major hydro power possibilities in the area.

As the demand for power increases, the hydro power produced by the Federal installations will be a progressively diminishing proportion of the total firm power needed to serve preference customers in the marketing area, and in time the hydro power developed at Federal installations may well be used to a large extent for peaking purposes to supplement the generation of power by other means." (Underscoring supplied.)

2. Development of the Bureau-Basin Electric Power Cooperative Hydro-Thermal Integration Plan

After the release of the aforementioned Seaton Report, many entities in the Missouri Basin commences transmission and thermal generation studies to determine the most effective way to use hydro peaking power. The Bureau indicated that by using the surplus energy from a 200-megawatt thermal unit it could sell as firm load factor power an additional 120-150 megawatts of load factor hydro power. After finding that there was surplus transmission capacity in the existing Bureau grid to deliver about 200 megawatts to power markets in the Missouri Basin, the Missouri Basin Systems Group was organized to further develop the "Joint System" of the Missouri Basin. Basin Electric Power Cooperative (called "Basin Electric") then proceeded to finance the world's largest lignite plant at a mine-mouth site near Stanton, North Dakota. The 200-megawatt generating plant was scheduled for operation in 1965, with surplus energy to be sold to the Bureau on the basis of fuel cost plus one-half mill per kilowatt-hour, with Basin Electric to receive emergency and backup service from the Bureau and transmission service from the Joint System at $4.90 per kilowatt-year based on nameplate generation. The Basin Electric 200-megawatt generating unit has been operating successfully as a base-load plant with the Bureau either utilizing or selling to other utilities all of the surplus thermal energy that could be generated. The Bureau was in a position to sell, on a long-term basis, a sizeable block of load factor hydro power on the basis of its long-term mutually beneficial arrangement with Basin Electric. Thus the hydro-thermal plan envisioned in the Bureau's 1952 report was underway.

3. Development of a Three-Party Hydro-Thermal Integration Arrangement

The second round of the Missouri Basin hydro-thermal program involved the Bureau, Consumers Public Power District of Nebraska (called "Consumers"), and Basin Electric. Consumers having a pronounced summer peak load, had developed plans to construct an 800-megawatt nuclear generating plant at Brownville, Nebraska on the Missouri River and had worked out arrangements to sell one-half of the capacity on a long-term basis to Iowa Power & Light Company. Basin Electric, having sold the output of its first 200-megawatt generating unit and having a winter peak load condition, developed plans to install a second generating unit of 400 megawatts in its Stanton plant with an in-service date of 1974.

Both Consumers and Basin Electric could effectively utilize about 280 megawatts of hydro peaking power based upon the available surplus thermal energy from their systems. Both Consumers and Basin Electric needed emergency and backup arrangements for

the new thermal and nuclear generation. The Bureau offered a package proposal which involved the sale of 280 megawatts of summer peaking power and 95 megawatts of year-round peaking power to Consumers and 280 megawatts of winter peaking power to Basin Electric under long-term power sales and interconnection contracts. The economic results of the package proved to be attractive to all parties and contracts were signed and the planned thermal generation and associated transmission additions are now underway. The Bureau has thus found a satisfactory long-term market for substantially all of its remaining hydro peaking power and the area is making the best overall use of this resource. Incidentally, during this time the Bureau also worked out a 50-megawatt winter-summer power exchange with the Southwestern Power Administration by taking mutual advantage of seasonal and hydraulic diversity between the two Federal hydro systems.

Based upon present forecasts, the new thermal generating units will be operated as essentially base-load units with the resulting overall economy associated with such operations.

Of interest to the commercial coal and lignite suppliers in the Missouri Basin is the production record of the first 200-megawatt lignite-fired generating unit of Basin Electric. Except for relatively short periods of time when Garrison Reservoir had to be lowered to meet predetermined rule curves, there has been a market for all of the surplus energy that Basin Electric could produce. To the extent that fuel costs can be maintained at a favorable level, it can be expected that most of the new thermal plants will be operated at base load, thus providing an attractive and steady market for the fuel suppliers. To the extent that interregional transmission lines can be constructed in the next decade, additional opportunities will develop that will foster more base-load thermal plants. Accordingly, the coal and lignite fuel suppliers can now foresee that stable long-term fuel markets will be developing in the Missouri Basin.

We believe, therefore, that the ground work has been laid for a further expansion of this hydro-thermal integration concept in the Missouri Basin. The Bureau, through cooperation with the U.S. Corps of Engineers, will maximize the use of reservoir capacity in the 76-million acre reservoir system on the Missouri River to facilitate the uniform loading of thermal generation. It is expected that the foregoing arrangement will permit the maintenance of a relatively satisfactory wholesale rate in the Missouri Basin to the mid-1970's. After that date, the next round of power supply expansion for the Missouri Basin must be ready for commercial operation. The Bureau is also studying plans which could transport a supply of cooling water for thermal plants that could be located at mine-mouth sites. This program merits the active support of the utility industry.

4. Plans for 1975-1980 in the Missouri Basin and the Rocky Mountain Area

The Corps of Engineers recently announced that an additional 1-1/2 million kilowatts of hydro peaking capacity can be added to the Missouri River system through the installation of additional generating units at existing plants and the operation of the Big Bend Project as a pumped-storage unit. This plan is based upon the anticipated availability of substantial quantities of low-

cost thermal energy for firming hydro peaking power and providing the necessary energy for the proposed pumped-storage project.

Based on information available from engineering studies and press releases, the following thermal plant sites are being actively considered for the period 1970-1980:

Plant Location	Probable 1980 Capacity Megawatts
Kaiparowitz - Utah	3,700
Ninemile - Rock Springs, Wyoming	1,000
Craig, Colorado	1,000
Hayden, Colorado	600
Midway, Colorado	700
Emory County, Utah	700
Glenrock, Wyoming	700
Four Corners, New Mexico	2,500
Stanton, North Dakota (Basin Electric)	600
Stanton, North Dakota (United Power Coop.)	650
Center, North Dakota (Minnkota Power Coop.)	700
Total	12,850

In addition to the foregoing plant sites, Basin Electric is currently studying several sites in Montana, Wyoming, and Western Nebraska. Montana Dakota Utilities Company, Otter Tail Power Company and Northwestern Public Service Company recently announced the construction of a 400-megawatt thermal plant for an undisclosed site in South Dakota. In addition, Heartland Consumers Public Power District of South Dakota is studying several plant sites in their state. In summary, some 14 million kilowatts of new thermal generation is in operation or under active study in the Missouri Basin and the Rocky Mountain areas in the 1970-1980 period. The prospects for major plants in Montana during this period do not look too promising at this time even though this state does have about one-tenth of the Nation's total supply of coal and lignite (about 221 billion tons) and substantial amounts of cooling water for thermal plant installations.

Perhaps the current lack of planning for new thermal generation in Montana may prove to be a "blessing in disguise" because there may develop a real opportunity to plan for optimum development of the use of Montana's vast fuel resources through construction of large mine-mouth generating plants in conjunction with plants that will convert coal and lignite to synthetic hydrocarbons. In addition, there may be opportunities to convert coal directly to electrical energy through MHD if funds can be made available promptly to continue basic research in this promising field. Of special significance is the fact that Montana may be in the fortunate position of having its power-producing and coal-conversion plants designed to protect and preserve the local environment. Furthermore, the utilities in Montana will not have to write off a large amount of inefficient generation as they can step right up to the use of large modern generating units.

This Coal Symposium is an excellent opportunity to bring the

resources of Montana to the attention of those business leaders who will be responsible for the expansion of the Nation's energy requirements. The Montana Congressional delegation, Governor Anderson and Eastern College of Montana are performing a real service through the medium of this Coal Symposium and we can expect to see tangible results of this effort in the decade ahead.

In the paragraphs that follow will be discussed the success of hydro-thermal programs in the Pacific Northwest in order to lay a proper foundation for the planning that must be undertaken if the billions of tons of coal and lignite in Wyoming, Montana and North Dakota are to be put to use under plans that are in the public interest.

C. HISTORY OF HYDRO-THERMAL INTEGRATION IN THE PACIFIC NORTHWEST

It has long been recognized that the loads in the Pacific Northwest would grow beyond the ability of the hydro power resources to meet them. The concept of installing thermal plants to supplement hydroelectric power during periods of low stream flow was established as early as the early 1930's when the Shuffleton Steam Plant of the Puget Sound Power & Light Company was installed to "firm up" the Rock Island Hydro-Electric Project. Soon after this installation, the further development of the Columbia River through the construction of the Federal and non-Federal hydro-electric projects was started. As the cost of power from the hydro projects was significantly lower than cost of power from steam plants, the installation of large hydro projects -- starting with the Bonneville and Grand Coulee projects -- eliminated the need for further thermal development at that time.

Accordingly, until just recently, the load growth in the Northwest since the early 1930's has been met through installation of additional hydro resources. As the loads in the Northwest continued to expand, however, it became apparent through long-range studies that these hydro resources would have to be supplemented by thermal facilities at the appropriate time. The Army Corps of Engineers, in its review of HD 531, 81st Congress, 2nd Session, presented its report dated June 1958 entitled "Water Resources Development of the Columbia River Basin". This report anticipated that power supply development during the period to 1975 would consist of essentially all-hydro installations to meet load. Between the years 1975 and 2010, the Corps report anticipated installations of both hydro and steam plants to meet load and termed this period the "transition period". The period after the year 2010 was classed as the "mature hydro-thermal period" and load growth was expected to be met entirely through installation of thermal plants.

The Hydro-Thermal Program, as now developed for the Pacific Northwest, follows, in general, the patterns suggested by the Corps in its 1958 study. Only the timing and details have been changed as a result of a number of factors unforeseen at the time of preparation of the Corps studies.

The present Hydro-Thermal Program did not "just happen". It evolved from a long history of cooperation between all utilities, Federal, public agency and private.

The foundation for the present cooperation between utilities

in the Pacific Northwest was laid in the early 1940's with the formation of the Northwest Power Pool. It further evolved during the 1950's when construction of a number of non-Federal hydroelectric projects was initiated until, in the year 1960, the need for complete cooperation between all segments of the power industry in the Northwest became essential. Probably the largest single element leading to formalization of this cooperation was the discussions leading to adoption of the treaty between the United States and Canada relating to the cooperative development of the Columbia River and its tributaries. Coming in rapid succession during the early 1960's were the negotiation of the Pacific Northwest Coordination Agreement, adoption of the Canadian Treaty and authorization of the transmission intertie between the Pacific Northwest and the Pacific Southwest.

The Coordination Agreement is an extensive document covering virtually all phases of coordination of operation of the generating projects in the Pacific Northwest. It provides the formal agreement by which the utility systems' water storage reservoirs are operated, by which maintenance and reserves are handled, and contains detailed operating procedures, obligations and entitlements to power from the coordinated system. In addition to the formal accomplishments within the document itself, it provides the forum for discussion of virtually all power supply issues facing the utilities in the Pacific Northwest.

The Canadian Treaty, ratified in 1964, provided for construction of additional storage reservoirs in Canada in exchange for 50% of the net benefits produced at downstream plants in the United States from construction of these projects. This reservoir construction has provided additional, badly needed hydro power in the Pacific Northwest. It also provided better control of flood waters and higher winter flows so that additional peaking capacity could be economically installed downstream.

At about the same time as the Canadian Treaty and the Coordination Agreement were entered into, the Federal Government and the utilities along the West Coast developed a plan for transmission interconnection between the Pacific Northwest and the Pacific Southwest. The plan called for construction of two 500-kv AC transmission lines and two 750-kv DC transmission lines with total capacity of about 4.4 million kilowatts.

The two AC lines have been completed and one of the DC lines is under construction. These lines permit power interchange between the Pacific Northwest and the Pacific Southwest. These lines have already proved their worth in providing markets for surplus firm and secondary energy from the Pacific Northwest and providing the basis for accelerating construction of at least two major fossil-fuel plants on the West Coast.

With the Canadian Treaty projects in Canada and the Libby Project in the United States under construction as a result of the Canadian Treaty, only a few major low-cost hydro projects remained for further development.

Another important development of the 1960's was the construction of the Hanford Electric Generating Project. This project was the first modern, large-scale, thermal plant to be constructed in the Pacific Northwest and was constructed to take advantage of the unique opportunity provided by the construction by the Federal

Government of the Hanford Dual-Purpose Power Reactor. This reactor, completed in 1963, was designed to produce plutonium and, as a by-product, to produce steam for power generating purposes. In pursuing this opportunity, the Washington Public Power Supply System, a joint operating agency of the State of Washington, was formed to act as a single agency to purchase the steam from the Atomic Energy Commission (AEC) and to construct a generating plant capable of using the steam to generate electric power and energy. The power output from the plant is sold to a group of private and public utilities. These utilities in turn exchange the output of the project with the Bonneville Power Administration (BPA) for firm power delivered to their load centers. BPA schedules the output of the Hanford Plant and, during periods of surplus hydro, can use this surplus to reduce generation at the Hanford Plant or to shut down the plant completely. This factor promises to be useful at such time as the Hanford Project is converted to a single-purpose project after its usefulness to develop plutonium for the AEC is at an end.

The cooperation of all the utilities in the Pacific Northwest was necessary in order to construct a plant of size and characteristics to most effectively use the available steam from the Dual-Purpose Power Reactor. Seventy-six participants, consisting of 22 utility districts, 18 municipalities, 31 cooperatives and 5 private utilities, are involved. The project is capable of developing 800,000 kilowatts of maximum generation and lesser amounts of average generation depending upon the operation of the reactor by the AEC for plutonium production. Construction of the generating facilities has resulted in two desirable effects. First, a portion of the waste heat from the reactor has been converted into usable energy to supply electric power load and second, by using a portion of this waste heat, the thermal effect of the reactor on the temperature of the Columbia River has been reduced.

The Hanford Project was completed in 1966 and just last month became the first nuclear-fueled generating plant to generate a lifetime total of 10 billion kilowatt-hours.

In order to meet the expanding power needs, further thermal power generation was required. The development of very large steam-electric units with their economies of scale made it desirable that this thermal generation should be in these very large units. Because the stage had been set for cooperation between utilities through the Coordination Agreement, the utilities working together evolved a Hydro-Thermal Program. This program makes use of the existing hydroelectric facilities through installation of planned peaking units to supplement new base-load steam units.

The use of hydro power for peaking purposes is, of course, well established throughout the Country. Hydro power is ideally suited for the role of providing peaking capacity because of its starting characteristics and its ability to use stored water for peaking purposes.

As the Hydro-Thermal Program was taking shape, loads continued to grow and construction of major projects could not be delayed. Accordingly, eight utilities in the Pacific Northwest proceeded with the development of the Centralia Steam-Electric Plant. This project, sponsored by the Washington Water Power Company and the Pacific Power & Light Company, was the first large-scale, coal-fired plant to be undertaken in the Northwest. This plant is to

be a joint-ownership plant with four private power companies and four public agencies jointly owning the plant as Tenants-in-Common. The plant is expected to produce about 14 million kilowatts using locally strip-mined coal as a fuel. The plant was originally scheduled for initial operation in 1974. The Bureau of Reclamation in California, however, required power in 1972 and, accordingly, arrangements were made to accelerate installation of the first 700-megawatt unit to late 1971 completion, permitting the sale of about 427 megawatts to the Bureau. Unexpected load growth and construction delays in other power projects forced revision of the scheduled completion of the second 700-megawatt unit so that it is now scheduled for completion in 1972.

This project was subsequently included in the formal Hydro-Thermal Program finally adopted. This program was developed jointly by Federal agencies, private companies and public agencies, and tentatively provides for the following plant operating dates:

Date	Plant	Fuel	Capacity (Mw)
1971	Centralia Unit No. 1	Coal	700
1972	Centralia Unit No. 2	Coal	700
1974	Trojan	Nuclear	1,100
1974	Wyoming	Coal	500
1975	Wyoming	Coal	500
1976	Eugene	Nuclear	1,100
1977	Roosevelt Beach	Nuclear	1,100
1978	Wyoming	Coal	500
1979	North Puget Sound	Nuclear	1,100
1980	North Puget Sound	Nuclear	1,100

The Trojan plant is sponsored by Portland General Electric with participation by Pacific Power & Light Company, Eugene Water & Electric Board and several Oregon public agencies. The Wyoming plant is jointly sponsored by the Pacific Power & Light Company and the Idaho Power Company. The Eugene plant is sponsored by the Eugene Water & Electric Board with participation by a number of public and private utilities in the Northwest. The Roosevelt Beach project is sponsored by the Washington Public Power Supply System and Grays Harbor County Public Utility District with participation expected by a large number of public agencies. One of the North Puget Sound plants is expected to be sponsored by the City of Seattle and the Snohomish County Public Utility District and the other is expected to be sponsored by Puget Sound Power & Light Company. Further participants in those plants have not yet been identified.

In order to provide peaking capacity to go along with the thermal installations and to provide transmission capacity to carry the power to market, the Hydro-Thermal Program proposes that hydro projects along the Columbia River and its tributaries be expanded by the addition of peaking units where feasible. Hydro pumped-storage projects, at strategic locations in the Pacific Northwest, will also be required and potential sites are being investigated. Where the hydro project belongs to the Federal Government, the Hydro-Thermal Program provides that the Federal Government will expand the project. Where the hydro project belongs to a public agency or private company, the program provides for the owner of the project to expand it. In all probability,

the initial pumped-storage projects will be financed by non-Federal utilities.

The transmission required is expected to be jointly financed with major additions to the Bonneville grid in the Northwest being financed by the Federal Government and transmission lines connecting the plants to the Federal grid to be financed either by the Federal Government or the individual plant sponsor depending upon circumstances. The Program expects to require almost $18 billion of total expenditures for electric facilities in the next 20 years. This includes some $12 billion of generation and transmission and some $6 billion in low-voltage transmission and distribution. About $3.7 billion is expected to be spent by the Federal Government for generating facilities and about $5.4 billion by the non-Federal utilities. About $2.4 billion is estimated to be required for Federal main-grid transmission and about one-half billion dollars for non-Federal main-grid transmission.

The availability of low-cost coal in the mid-continent areas of Montana and Wyoming may offer a unique opportunity to provide some of the generating capacity needed in the Pacific Northwest through use of at-site generation and extra-high-voltage transmission lines. Although initial studies show that the cost of transmission from the coal areas to the Pacific Northwest increases the cost of power from coal plants above the costs of power supply from nuclear plants located near load centers, the current problems of siting nuclear plants in the Northwest may create situations which would make it desirable to supply some of the load through use of Montana and Wyoming coal. Furthermore, the possibility of constructing transmission lines from such coal plants to the Missouri Basin, thereby providing an East-West intertie with coal plants in the middle, offers an attractive field for further investigation. Attached is a map showing the major transmission systems in the West with major coal-producing areas superimposed.

The important possibilities of the use of diversity between the two very large hydro systems of the Bonneville Power Administration on the one hand and the Bureau of Reclamation in the Missouri Basin on the other, coupled with the time diversity between the two areas and, more importantly, the temperature diversity, should be explored. The Pacific Northwest with its substantial electric house-heating load has increasingly sharp peaks in the winter that are a function of cold weather extremes. Generally speaking, these cold weather extremes cover the entire Pacific Northwest area at the same time and, accordingly, there is little, if any, peak diversity between utility systems. If, on further study, it is shown that extreme low temperatures in the Missouri Basin do not coincide with the extremes in the Pacific Northwest, the output of a coal-fired plant located at the center-point of a transmission interconnection between the two systems could be used to meet the extremes of each area and, accordingly, to the extent of load diversities, provide a dual function and a substantial dual benefit.

D. NEW AREAS OF POWER INTEGRATION

The potential use of Magnetohydrodynamic Generation (MHD) will be the subject of several technical papers at the Montana Coal Symposium. Senators Mike Mansfield and Lee Metcalf have recently urged the Department of the Interior to sponsor a $50

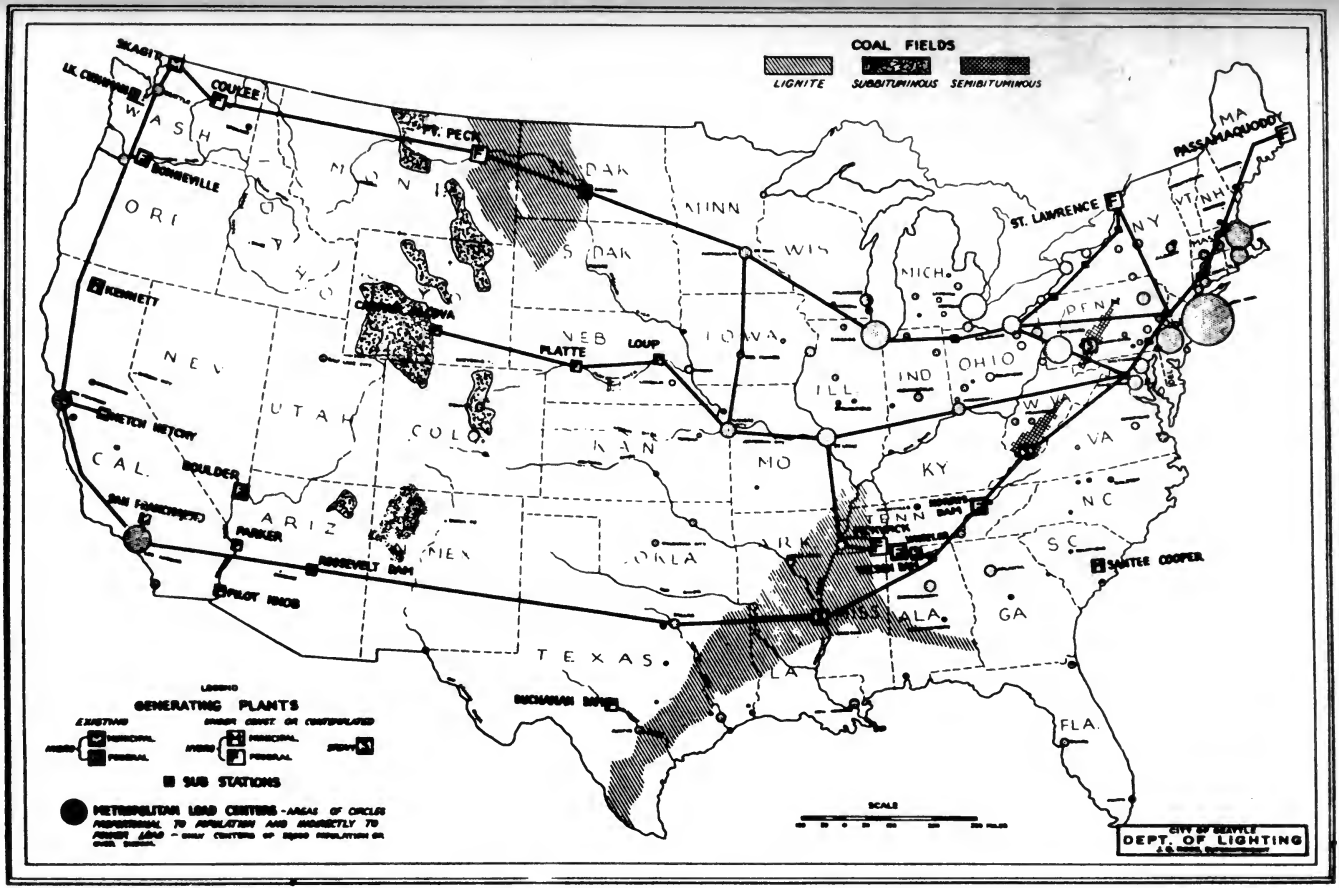
million research program so as to hasten the prospect of using this new energy conversion process in the Missouri Basin and thereby make effective use of the enormous coal and lignite resources that have now been verified. According to the report entitled "Energy R&D and National Progress" which was prepared by the Office of Science and Technology in June 1964, the output of an "open-cycle" MHD generator "... would be direct current at reasonably high voltages (in the kilovolt range)." The August 25, 1969 issue of the "Electrical World", page 50, had the following progress report to make on MHD generation:

> "A first-generation 1,000 Mw open-cycle magnetohydrodynamic power plant burning natural gas or coal could be in operation by 1980 at a capital cost of $100 to $120 per kw. Half the power would come directly from MHD and half from a conventional steam cycle. It would show a 20% fuel saving compared with a conventional plant this size, would use less than half the cooling water, and cause practically no air pollution."

In our opinion, there is ample justification to perform further research on high-voltage, direct-current transmission so that this mode of power transmission can keep pace with research on MHD generation.

At the present time, the Bonneville Power Administration is the only utility in the United States that plans on the early use of 750-kv DC transmission for a part of the Pacific Northwest-Pacific Southwest Intertie. We understand that the Bureau has postponed to the late 1970's the DC transmission line planned as their participation in the aforementioned intertie. Accordingly, there is an indication that this important mode of power transmission may be put "on the back burner" for a period of time in the United States. Furthermore, Transmission Study No. 190 which made extensive analyses of cross-country EHV transmission lines, both AC and DC, has not found general acceptance with the utilities in the Northwest and Southwest.

It seems probable, through further research and study, that MHD generation will be found to be fully compatible with existing and planned hydro generation, in which event future studies will be devoted to improving the "generation mix" for particular areas, including conventional hydro, pumped-storage hydro, fossil-fired thermal generation, nuclear generation, and MHD. It seems most timely, therefore, that any research program that is sponsored by the Department of the Interior include funds for MHD generation and DC power transmission. Hopefully, Senators Mike Mansfield and Lee Metcalf will actively pursue their endeavors in this very important field and hasten the day that full and effective use can be made of the coal and lignite fuels in the Missouri Basin in fulfillment of the area's energy needs and with due regard for the best use of our natural resources and protection of the environment in the "Big Sky Country".



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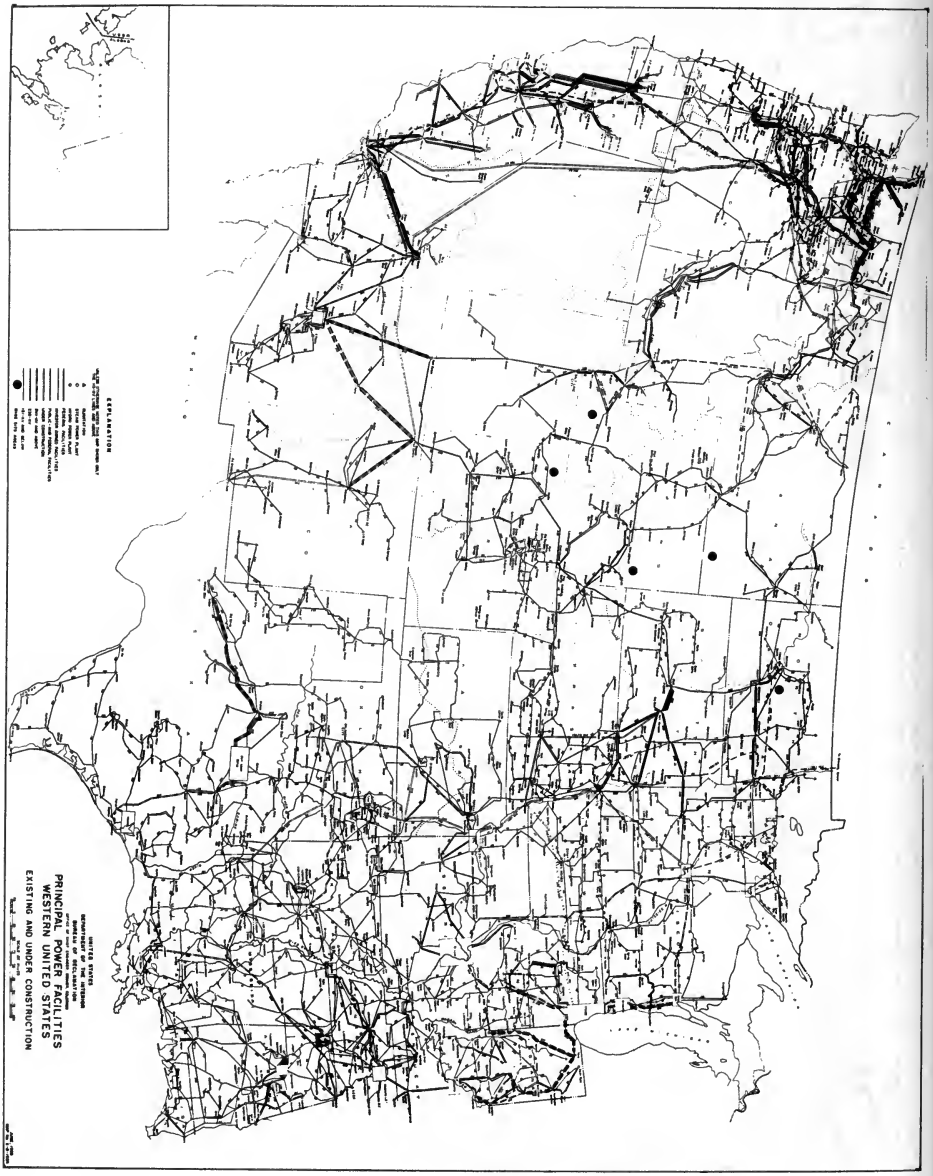
ANALYTICAL AND CONSULTING ENGINEERS


PRINCIPAL POWER FACILITIES
WESTERN UNITED STATES
EXISTING AND UNDER CONSTRUCTION

PANEL: COAL MINING AND EXPORTING TECHNIQUES

Remarks of the Panel Moderator, A. J. Silverman

It is a pleasure and an honor for me to be here today, and to participate in this outstanding program. We have a distinguished panel for our last session of the day, which will be devoted to Coal Mining and Exporting Techniques.

We have been fortunate today to have heard an eloquent expression of our national and regional power needs and problems. This was followed by a description of regional power development programs in the process of completion, as well as those being planned.

Our last panel of the day will tackle the problems and progress in coal strip mining, marketing and transportation. These are crucial subjects that strike at the economic core of coal development in Montana and the surrounding region.

Arnold J. Silverman, University of Montana, Missoula, Montana.

MOVING THOSE 8500 BTU'S

R. E. Miller

There are billions of tons of low cost strip coal available for mining in Montana --- we've all heard this statement before --- and we'll hear it again before this meeting ends. So what's new???? It's not the coal nor its presence --- geologists have known about it for years. The new and important fact -- the exciting fact --- about Montana coal --- is its potential marketability. The markets are distant, some in mileage, some in time. They are distant but they can be reached --- IF.

At our previous session, we heard about the tremendous future fuel requirements of the utility industry in the western part of the United States. Those of us who calculated a few figures would properly conclude that 5 or 6 hundred millions of tons of Montana coal COULD be required to partially fill that growth. And with extra high voltage transmission lines and unit trains eagerly waiting to deliver that energy to the distant markets, all we have to do to market good old Montana coal is pick up a stripping machine and a few haulage trucks and get ready to dig! IF ---

Enough of the preliminaries --- let's get to the main bout and get the IF's on the table.

The first IF --- WATER.

For either steam electric generating plants or the gasification and liquefaction processes, large amounts of water are required. The State of Montana has sufficient amounts of water available for such projects, far more than most of the other states in the west. Montana must endeavor to make its water available on readily workable terms and conditions.

Our Company has worked with the State of Montana for a number of years in an effort to get something definitive on the Tongue River. We've found those concerned most cooperative and eager to discuss the situation, but at this date, no workable solution has been devised. Meanwhile, the Bureau of Reclamation has moved ahead with contractual arrangements on waters from the Yellowtail Reservoir. A potential energy customer can now firmly evaluate fuel and water costs at one location and be assured of the availability of both. I'm hopeful that we can soon present a similar picture on the Tongue. Perhaps the state should consider the necessary appropriations now to enlarge the Tongue River Reservoir. Ultimately, the water users would pay the cost of the enlargement but the state's foresight and leadership in expanding the reservoir now would make this important resource a valuable tool in accelerating the development of coal projects in the Tongue River area.

IF NO. 2 --- REASONABLE TAXATION AND REGULATION.

As we enter this era of the potential development of Montana

Richard E. Miller, Senior Vice President, Sales, Peabody Coal Company, St. Louis, Missouri.

coals, I am hopeful that we all keep a few basic ideas in mind:

1. There are other states in the west which have large reserves of low cost coal,

2. There are fuels other than coal available to the electric utility industry, and

3. The degree of competition in the selection of a fuel or plant site is very intense in almost every instance.

Last year, there was a bill introduced in your legislature to impose a 50¢ per ton tax on each ton of coal mined in Montana. Notwithstanding the additional penalty effect on the transportation element, this would have disadvantaged some Montana coals by 2½ - 3¢ per million Btu's when compared to coals from neighboring states. Most of you are well aware that a specific fuel or a specific supplier is selected on a far lesser margin.

This year, Montana's Senator Metcalf has re-introduced a bill, designated Senate Bill S. 910, which would impose a federal severance tax of 5% on the gross income from all domestic mineral properties. A credit against this tax is allowed to the extent which a state or local authority imposes a similar severance tax. This is tantamount to inducing states to levy their own full 5% tax and I'm certain they would do so.

At first blush, Senator Metcalf's bill appears to have the advantage of imposing the same burden on all coal producers in all states and it does generate some sorely needed revenue for the states. But does a 5% tax on gross mine price REALLY impose the same burden on all coals from all states, regardless of their Btu value, when they are competing in distant markets? I think not. And I haven't yet been able to fully evaluate the effect of this proposed tax in connection with other fuels.

If a utility is evaluating a nuclear plant using Colorado produced uranium and a fossil fueled plant using Montana produced coal, does a 5% severance tax on both minerals maintain the same competitive relationship? I am hopeful that it does, but I believe the tax might over-penalize the lower Btu product.

The third IF --- UTILITY COOPERATION.

If Montana coal produced energy is to reach the large load centers using extra high voltage transmission lines, a spirit of complete cooperation must exist between the investor-owned and public power groups.

The utility industry has already made much progress along this line, particularly in the western states. The spirit which has prevailed in WEST in the southwest and in the Joint Power Planning Council in the Pacific northwest must now encompass southeastern Montana and the surrounding states if Montana coal is to gain a large share of the western and midwestern utility growth. To be competitive, energy generated from Montana coals in Montana must move to market in large volumes and I can envision no one market area where an investor-owned or public power group could transport and consume the total energy without help from the other.

In summary, we at Peabody are optimistic about selling Montana coal. We're dedicated to making this energy source the most widely travelled bunch of Btu's in the west by wire, rail or slurry pipeline. We're hopeful that these eager to travel Btu's aren't tied down, never to see the light of day, by red tape and unreasonable regulations.

STRIP MINING

E. R. Phelps

As you have noted, the title of my paper is "Strip Mining" and I have been told that ten minutes is the maximum time allotted; but even with my limited knowledge of the subject, it is extremely difficult to determine what portion of this rather broad mining concept should be discussed. Since this symposium is for Montana resource development, primarily coal, I will start with Montana coal as such.

First, and most important in any mining proposition, is the reserve situation and in this case, the United States is extremely fortunate when we discuss the amount of coal reserves. I believe this is one of the few instances when the Russians do admit the American superiority. The latest compilations by the experts show that the United States has 32-1/2% of the total world's remaining coal reserves, followed by the United Soviet Republic with 25.9%, then China showing 21.8%, and the next or fourth is Germany with only 6.2%. This 32-1/2% of the total world's coal reserves found in the United States is located in some 34 of the 50 states and is being actively mined in 26 of them.

The United States Geological Survey has compiled a list of coal reserves that have been determined by mapping and exploration work and have an over-burden thickness of less than 3000 feet in this list.

Montana leads in bituminous and sub-bituminous coal; however, if lignite is included, North Dakota does have a greater total. This listing shows 378 billion tons of coal in Montana. In order to really comprehend the magnitude of this, one must compare this estimated tonnage with the total tonnage of coal mined in 1968 in the United States. In so doing, one would find that there is sufficient coal in Montana to furnish an additional 750 years of mining at the 1968 rate. According to the United States Bureau of Mines' records, there has been only 180 million tons of coal mined in Montana from the earliest record to date; so it is easy to see that the potential coal reserves in Montana have barely been scratched.

Going from this discussion of total coal reserves to the strippable coal remaining in the United States permits us to discuss the strip mining industry as such. In strip mining, the output per man day is roughly 100% higher, overall recovery is 60% higher, and operating costs are 25-30% lower than in underground mining. These significant economic advantages have caused the tonnage of strip coal produced by strip mining to increase steadily over the years. In 1917 strip mining accounted for only 1% of the total United States production; whereas in 1966 it amounted to 33.7%. The increased production by strip mining has been accompanied by continued improvement in the size and efficincy of earth moving machinery. In 1917 the largest steam shovel in operation had a capacity of only a few cubic yards. By 1957 the largest shovel had a capacity of 70 yards and in 1965 the

Edwin R. Phelps, Senior Vice President, Operations, Peabody Coal Company, St. Louis, Missouri.

largest shovel in operation had a capacity of 180 yards. In 1968 a dragline of 220 yard capacity was completed. This machine will be capable of removing 10,000 cubic yards of material per hour and dumping it some 310 feet from the center line of the machine.

The increase in size and efficiency of strip mining machinery has permitted a steady increase in the average maximum thickness of over-burden that can be removed and a parallel increase in the ratio of average overburden thickness to average coal thickness. In coal strip mining the ratio is defined as "the number of cubic yards of overburden required to be removed to uncover one ton of coal." In 1946 the average thickness of overburden removed was 32 feet and the average thickness of coal removed was 5.2 feet giving a ratio of 6 to 1. In 1965 the average thickness of overburden removed had climbed to 50 feet and with the same 5.2 coal thickness, the ratio increased to 10 to 1 and the maximum thickness of overburden had also increased to some 125 feet. We have mines in Missouri and Oklahoma where the average coal thickness is as thin as 1.5 feet and the average overburden as high as 45 feet which yields a ratio of 30 to 1. This does not mean that 30 to 1 ratio is technically feasible as an upper limit. However, it does prove that under certain conditions it is acceptable. There are many economic factors which affect this, such as the thickness and quality of the coal, the density and hardness of the overburden, the capacity of the machinery, the size of the property, the selling price of the coal from competing sources, the distance to transportation facilities and markets, and the availability of electric power, labor and supporting facilities.

From a conservation standpoint, strip mining is by far the most superior method of mining. First -- it does increase the amount of automatically recoverable coal, for by this method, the average recovery is 95% as compared to 50% for underground mining and second, it does permit the mining of coal which is too thin or too shallow or too faulted or in such small isolated pockets, it would be impossible to mine by the underground method.

The increase in size and efficiency of strip mining machinery has also made it possible to state that the total remaining recoverable stripping-coal resources in the United States within the 0-100 foot overburden are about 100 billion tons. This figure is 27 times the cumulative strip coal production from the beginning to now and is equal to 600 years of present annual strip production.

In eastern Montana 59 potential strip mining localities, underlain at shallow depth by 5 billion tons of coal have been reported in United States Geological Survey reports. This figure of 5 billion tons of 2.4% of the total coal resources in eastern Montana as determined by mapping and exploration. This is obviously less than the total strippable coal present and reviewing the potential sites where the coal bearing rocks are concealed by glacial deposits the total potential stripping reserves of Montana have been estimated at 15 billion tons, which is equal to 75 years of last year's estimated 200 million tons of total strip production.

Since the largest reserves of strippable coal remaining in the United States are located in North Dakota and eastern Montana, these reserves are of extreme value. In the past, relatively little mining has been carried on in these states, because of the

small population and the lack of industry located with practical haulage distances. With the advent of the large generating plants in the size ranges of 800 to 1,000 megawatt capacity and the use of EHV (extra high voltage) transmission, it is possible to transport this coal (in effect by wire) to areas of large demand. In addition, with the advent of the unit train concept of coal transportation and the proving of pipeline for slurry, the transportation portion of the final fuel costs at the power plant has been drastically reduced and this also has improved the competitive position of the Montana coal reserves.

I am certain that having listened to the panelists who preceded us, there is no question in your minds as to the vital role coal must play in meeting future power demands.

As I stated earlier the economical advantages of strip mining, as a result of the higher tons per man day output, the lower operating costs and the higher recovery, serve to make the future of coal mining in Montana by the strip method of major economic interest to the state and to the users of energy.

As with most things in this world there are always disadvantages to counteract the advantages and strip mining certainly has its share of problems. I refer particularly to the relationship with the environment -- (air, water, and land) but more specifically, reclamation practices. I realize that these will be discussed in detail tomorrow; but as an operating man and as an executive who is interested in the future of our mines, both as to production and economics, we must have cooperation from the state and federal officials. Given opportunities to experiment and determine the best type of work to perform on each particular area, the final results obtained will turn out to be acceptable to both the public and the mining companies; whereas, regulations conceived as a result of public hysteria and "hurry up" legislation will only result in increasing the cost of mining. The public, of course, ultimately pays these unnecessary increases and the mining companies will be forced to look for alternate areas. I feel confident that the major purpose of this symposium is to further mining opportunities in the State of Montana and our experience here and in other states shows that when mines are being planned, all kinds of cooperation is promised; however, after the mines begin operation, this same cooperation seems to disappear. When we operate a mine in an area, we like to become a first-class citizen of that area and I am sure you will find by checking in other areas that we expend a great deal of effort toward this aim, but it does require an opportunity for experimentation, help and cooperation from all the various agencies and associations. When one begins to discuss ecological objectives, it is very difficult to match these with economical objectives. (To prove the point of new regulations, I wonder how many in this audience could give me a true definition of ecological values. This is one of the considerations that the new rules and regulations take into effect concerning our reclamation.) I am not trying to interject any political aspects to this discussion, but the State of Montana already has a 5¢ tax on coal and, to my knowledge, this is the only state that has such a tax. What I am suggesting for your consideration is, in order to fully exploit the enormous strip reserves of coal in Montana, you must interest large mining companies to construct and operate mines in Montana. Please give us an opportunity for cooperative study with all the various agencies in order to furnish results that will be acceptable to all concerned.

UNIT TRAINS

R. D. Pederson

This has been for all of us a most interesting day and one cannot help going away reflecting on the tremendous future of Montana's wealth in coal -- and at the same time the responsibity, the big responsibility, that we all share in seeing that this resource is developed in an orderly manner with due regard to environment and the balance of nature.

The emphasis today has been on the future and rightly so; but if my few minutes before you today serve no other purpose than to repeat and unlerline the fact that Montana coal is moving to its markets -- today, then my time is well spent. The coal is moving. It's moving by rail (by NP rails) -- by that acme of efficiency of the steel wheel on the steel rail. The coal is moving in quantities, 10,000 and more tons per train, and over distances, 800 plus miles at a time. A few years ago we would have been skeptical. Montana coal is moving, but we have only seen the beginning.

I am here to tell you something about unit trains, a subject worthy, by itself, of a symposium such as this. In the few minutes available we can only touch on the subject in general.

I am not an expert on unit trains. Many of you who represent the coal producers and the large consumers are the real experts for you probably have a very comprehensive knowledge and understanding of the subject, being that unit trains have been a very important part of the power production picture in the East, Southeast and Midwest for about ten years now. I presume by now you are all picturing a locomotive with 100 or so cars of coal -- nothing else except the caboose, all headed for the same destination.

I have consulted the writings of experts to bring you a pat definition of the unit train, but could find none. Instead there seems to be criteria that must be met, characterized chiefly by efficiency, balance and utilization.

Efficiency means the expeditious handling of a movement with the lowest out-of-pocket cost possible. Balance means finding the proper inter-relationship in capital costs between loading facilities, railroad equipment and unloading facilities, all with respect to the capacity needs of the system. Now utilization could be grouped properly under efficiency, but it is of such extreme importance in minimizing capital investment in railroad equipment, through a high rate of use, that it must be singled out and considered. If economics have been worked out to include a fair return on the investment, then the unit train approaches the ultimate achievement for a rail carrier.

Coal is probably the ideal bulk commodity which lends itself to handling in unit train movement. Coal gave the concept its start in 1960 when the Southern Railway began service between

Robert D. Pederson, Assistant to Vice President, Operating Dept., Northern Pacific Railway Company, St. Paul, Minnesota.

Southern Electric Generating Company mines and their power plants in Alabama. It was a big operation -- 240-100-ton aluminum gondola cars carrying in excess of 13 million tons. Unit trains really got rolling, however, after the President of the United States asked Congress in 1962 to provide the right of eminent domain to coal pipe lines. Within months, most major coal carriers were operating unit trains and at present we know there are well in excess of 500 such operations accounting for probably half of the coal shipped via Class I railroads. This has saved the consumer millions of dollars while improving profit picture for the carriers.

Equally important, a marketing tool was discovered, for the rail carriers could see that the unit train concept was ideal and that it could be adapted to other bulk commodities or high volume commodities offering savings to the shipper by "pricing" or cost-based rates. Thus, Alumina, taconite, steel ingots, automobile parts, to mention just a few, move in unit trains on the rail common carriers.

What are some of the more significant economic factors to be considered in pricing the service? We said earlier that a unit train had to be capable of efficiency with lowest out-of-pocket cost possible. The railroads have their investment in roadway, or route if you will, which in turn has latent capacity, so the things we have to look at before pricing are the cars, optimum train size, motive power, train turnaround time and train crew wages. Let's take a brief look at some of the general questions to be found in each area as they pertain to coal.

The cars. Aren't all coal cars quite a bit alike? It may look that way but we have a choice of a solid bottom for rollover dumping or a drop bottom with or without rapid dumping capabilities -- each at quite a different cost, of course. Do we want 100-ton of 125-ton cars or something else available that might be in between? Do we want aluminum body cars with higher net capacity but also higher initial cost, or do we want steel, in which case we may have to buy more cars to haul the same net amount of coal? What are the relative maintenance costs? Do we want standardization to give us interchangeability? Can the consumer take just any car or does he have built-in constraints? Have we achieved the balance we talked of earlier between loading, cars and unloading investment? Do we or does the shipper want to own the cars? The questions could go on but the point to be realized is that each of the questions and others similar must be analyzed and resolved working, where required, with the coal producer and the consumer.

What should the size of the train be? There will be some optimum point where the advantage of spreading the fixed costs per train (that is cost such as dispatching, roadway, traffic control, etc.) over more commodity becomes offset with the rising cost effects of the more difficult operating problems encountered in handling excessively long and heavy trains. What operating problems? The most obvious is grades which in turn accounts for two distinct problems -- drawbar pull and braking. Another is the optimum use of the tractive effort and this becomes a larger problem all of the time as locomotive unit horsepower increases. What I mean is that if we decide, for example, that the optimum train is 95 cars, this may just be slightly more than four units of 3600 horsepower each could handle at the speed we have deter-

mined for the train, so we have to add a fifth unit which gives us excessive capacity. This is really more a problem in selecting motive power but it relates because there are, after all, only certain models and horsepower groups to choose from. For interchangeability, we do like some degree of standardization. There are other operating considerations such as siding length, cold weather problems, signaling or traffic control, excessive rail wear, etc.

There are usually other considerations and constraints that enter also. It could be the frequency of delivery required by the consumer's unloading and stockpile capabilities or even plant trackage. It could be loading schedules and capabilities at the mine.

Motive power requirements were just touched on in connection with optimum train size. One power innovation, which Northern Pacific also uses, is the "slave" or remote controlled units within the train consist. Briefly, it consists of a master or control unit on the head end manually operated which transmits commands by radio signal to the unmanned remotely controlled units back at about the two-thirds point in the train. The slave is made up of regular line locomotive units tied together by a control car and what it does for us is spread out the tractive effort through the train so that drawbar pull on the front cars is not exceeded because of the extreme weight trailing. Problems with slack running in or out over this long train are significantly diminished. Also, and of particular importance to Northern Pacific which operates through some quite severe winter conditions, is the aid that this arrangement provides in overcoming the potential brakeline air pressure leakage which is a problem in long trains in cold weather.

You may wonder why the exact power requirements of the train is not achieved through the mixing of high and lower horsepower units. When this is done, the lower rated units place operating restrictions on the higher rated units, which results in inefficiencies which the unit train concept cannot stand.

Train turnaround is a big area for savings. By-passing terminals resulting in terminal time reduction is probably the biggest area for savings. Keeping the train intact, including the locomotive, through loading, running, unloading and returning is also significant but these advantages can easily be lost if the best, and yet closest possible schedule, (to do this we must take into account time and facilities, speed over the road and meshing in with the regular operations and unloading capabilities) is not worked out.

Schedule will reflect on crew time and wages, as well as car and motive power utilization. Savings available here are related to time but there is less work involved in terms of switching, train make, "desk work" (since there is usually only one waybill for all cars), etc., and theoretically it should take fewer people. Present labor agreements restrict any variance in the size of crew.

Privately operated unit trains are leading the way in terms innovations not yet possible for the common carrier. I think you are all aware of the really significant achievement in the fully automated privately-owned 15-mile long Muskingum Electric Rail-

road near Cumberland, Ohio. Two automatic trains haul 18,000 tons per day. I'll leave the rest to your imagination.

So far, I have been talking very generally, and hopefully, it has been demonstrated to you that putting a unit train operation together takes a great deal of analysis and decision making before the pricing of the service can be firmed up, although there is always the knowledge of what to expect by way of competitive fuel costs delivered to the consumer to serve as a guideline. Now we don't just add fixed costs and a profit margin and begin to haul coal. The real job of pricing begins when the coal producer takes his costs and necessary return and the railroad does the same, they put them together and try to arrive at a fair balance point where that coal can be delivered to the consumer at a price lower than the competition and still be profitable to partners in the coal rate.

Let's bring the subject here to Montana, to this very day. Sometime late today, 100 empty hoppers will pull into Forsyth. By tomorrow at 6:00 p.m. those cars will be coming out of the Big Sky Mine loaded and on their way to Minnesota Power and Light at Cohasset. Three big 3300 or 3600 horsepower diesels will be on the head end with two more cut in as slaves about 60 cars back. Saturday at about 3:00 p.m. that train will be turned over to the Great Northern. This is an interim movement without the benefit of rapid unloading capabilities but even so, the Great Northern takes these cars to Cohasset, unloads them and returns them in 34½ hours; they are back at the mine over Northern Pacific rails in another 18½ hours. At present this loading out takes place every fourth day.

In 1973, when their new 350 Mega Watt plant goes on the line, the coal will be transported in two train sets of 102 solid bottom cars each and five high power locomotive units, two acting as slaves, making two round trips per week each. They will operate on a total elapse time per cycle of 76 hours and 45 minutes. This arrangement will be capable of delivering the two million plus tons required annually at this new installation of Minnesota Power and Light.

Northern Pacific is very proud to be a partner with the Peabody Coal Company and the Great Northern Railway in delivering Rosebud County Coal to Cohasset. Mr. McGuire (Mr. McGrath) of Minnesota Power and Light gave you some insight into their economic considerations of using this coal in his talk this morning. We have demonstrated that, even with two railroads involved in the line haul, we can move this coal to beat the competition 837 miles away -- the longest unit train haul yet! This experience has given us the confidence to explore, with the producers, other markets in the midwest in Minnesota, Wisconsin, Iowa and even Illinois and we are now turning our sights to the potential west coast markets. We have studies underway right at present to see what we can do to make unit trains over the mountains a reality. If you will think back to the criteria of a unit train and the economic factors, you will believe me when I say this is a challenge, but we are confident it can be done within the realm of economic feasibility.

Ladies and gentlemen, I have attempted to tell you a bit about the unit trains that are now running, but if as you are traveling in the area this week or anytime soon and your eye is

caught by 100 or so heaped coal cars streaking down the track behind a team of humming NP diesels, just remember that this is Montana on the move - now - to the nation's markets and that coal is being carried as much by the rail industries' imagination, determination and dedication to serve as it is by the cars and track.

THE IMPORTANCE OF SLURRY PIPELINES FOR WESTERN COAL DEVELOPMENT

E. J. Wasp

The Western States have enormous coal reserves which they wish to develop, but they also wish the development to be carried out in a way which will least distrub the environment. Slurry pipelines have a very minimal affect on the environment since they are buried, and except for a pump station every 60-80 miles, there is no evidence by sight or sound that vast quantities of energy are being transported. They, therefore, do not offer offense to that segment of our population which views high tension power lines as a source of visual pollution.

A feature of slurry pipelines which is of special significance to the utility industry is their high degree of reliability. Power generation can be brought nearer to its natural load center and the exposure to black-outs is therefore reduced. Also, severe weather, such as snow storms or very low ambient temperatures, does not affect pipelines. The Consolidation Coal pipeline, for example, had an availability factor of 98%.

Slurry pipelines can be automated. The three-station Ohio coal pipeline and slurry plant was operated with one man. Similarly, the four-station Black Mesa line including the slurry plant will be operated with one man at the feed end and with one day man at each station. Slurry pipelines are, therefore, relatively immune to the effect of escalation with this low labor element. Approximately 70% of the unit cost of transportation is made up of capital-related fixed costs. Nearly half of the remainder is accounted for in power costs, and power historically has been stable and has even declined in some areas. Thus, about 85% of the annual transportation costs may be considered as virtually immune to the effects of escalation. Further, when one considers that in the Western States strip mining (which is capital intensive) would be used instead of underground mining (which is labor intensive) then, of the delivered price of coal to the power plant, assuming an 800 mile slurry pipeline, we have calculated that only 20% of the final price would be labor-related.

The economics of slurry pipelines compared to other modes of moving energy are shown on Figure 1. The figures shown on the figure are based on moving energy from point "A" to point "B", a distance of 500 miles. It can be seen from this figure that coal pipelines for all cases with capacity in excess of three million tons per year are more economical than EHV transmissions. In the case of the EHV costs, no inter-tie advantages have been taken.

Unit trains are somewhat more competitive. For a unit train rate of one-half cent a ton mile, then the capacity must be in excess of six million tons per year in order for the coal pipeline to be competitive. This level of coal consumption would occur with a 1,500,000 KW station using 11,000 BTU/lb. coal. One

Edward J. Wasp, Slurry Development Manager, Bechtel Corporation, San Francisco, California.

important factor which must be appreciated in reviewing Figure 1 is that it assumes that the unit train distance and coal slurry pipeline distance is the same. This usually is not the case since it would be extremely fortuitous that the power plant, its water supply and the coal mine were all on existing tracks in a straight line. Usually some spur tracks have to be added and in some cases routing of the trains is quite circuitous.

Frequently the question is raised as to how much water is required for coal slurry pipelining. Perhaps the best way to answer this question is that in the case of the Black Mesa pipeline the water requirement for pipelining would be one-twelfth the requirement of that needed for the power plant. Again in the case of the Black Mesa pipeline, the water is, after relatively simple treatment, suitable for cooling tower makeup. The water quality is about the same as clear Colorado River water.

I would like to discuss a point that is raised frequently and that is, if all these advantages exist for slurry pipelines, why did the Ohio Consolidation Coal pipeline shut down?

I will attempt to answer this question and would like to make the following relevant points:

1. The Ohio line operated for six years and in that time transmitted about one and one-quarter million tons per year. The coal company felt that the pipeline was an unqualified technical success. For example, after six years of operation (1957 to 1963), there was no evidence of wear on the pipe wall. Even the original mill scale was present.

2. Texas Eastern Transmission Company with Consolidation Coal Company joined together and planned to build a twelve million ton per year coal pipeline to the East Coast. Serious negotiations were under way with the Eastern utilities in 1962.

3. To make coal slurry a more attractive fuel than railroad coal, Consolidation Coal and Texas Eastern joined together to demonstrate the direct firing of concentrated coal slurries at the Werner station of Jersey Central Power and Light. This 60 megawatt station was fueled for a month in late 1962 by coal slurry fired very much as one would fire fuel oil. The utility people were most impressed with the elimination of the need for belts, bunkers, and crushers. In their place a liquid handling system of tanks and pumps was used. The station during the month's firing of coal slurry was physically as clean as a gas fired station. The utility operators were delighted with this and other aspects of the tests.

4. President Kennedy requested in his State of the Union Message in January 1963 that the Right of Eminent Domain be afforded to coal slurry pipelines.

It was the succession of these events, the six years of successful operation of the Ohio pipeline, the joining of Texas Eastern with Consolidation to build the twelve million ton line to the East Coast, the successful Werner tests, topped finally by the President of the United States requesting Eminent Domain for

slurry pipelines, that brought the railroads to effect substantial rate reductions in Ohio and the East.

The Ohio line was, therefore, an economic success. When the pipeline first started operation, freight rates to the Cleveland markets from District Eight were about $3 a ton. In order to shut down the Ohio pipeline it was necessary for the railroads to offer a $1.90 a ton rate or in excess of $1.00/ton reduction for not only the pipeline coal, which, as mentioned, was only 1.25 million tons per year, but all the coal out of District Eight in Ohio. There was five million tons per year of coal moving from this district. Very attractive terms were offered to the coal company to terminate the operation and they accepted.

Fortunately for the development of Western coal, we have a rebirth of the slurry concept in Arizona as shown on the route map in Figure II. Southern Pacific Railroad Company will be owners and operators of this 18-inch 275-mile coal slurry pipeline. It will have four pump stations and a capacity slightly less than six million tons per year. A photograph of a typical main line pump unit is shown in Figure III. One of these units will be capable of pumping approximately three million tons per year. The line will be put through its tests in the Spring of 1970 with commercial operation starting in July of the same year.

We think that the future for slurry pipelines is especially bright in the West because by this means the Western low-sulphur coals can be delivered to the Midwest or Northwest markets in the 20 to 25¢ range for large power stations. To the best of our knowledge this is below the present breakeven fuel cost of atomic energy.

The Western Utilities should, therefore, be congnizant of the economic importance of seriously factoring slurry pipelines into their transportation comparisons along with unit trains and EHV in their search to obtain the best value for their transportation dollar.

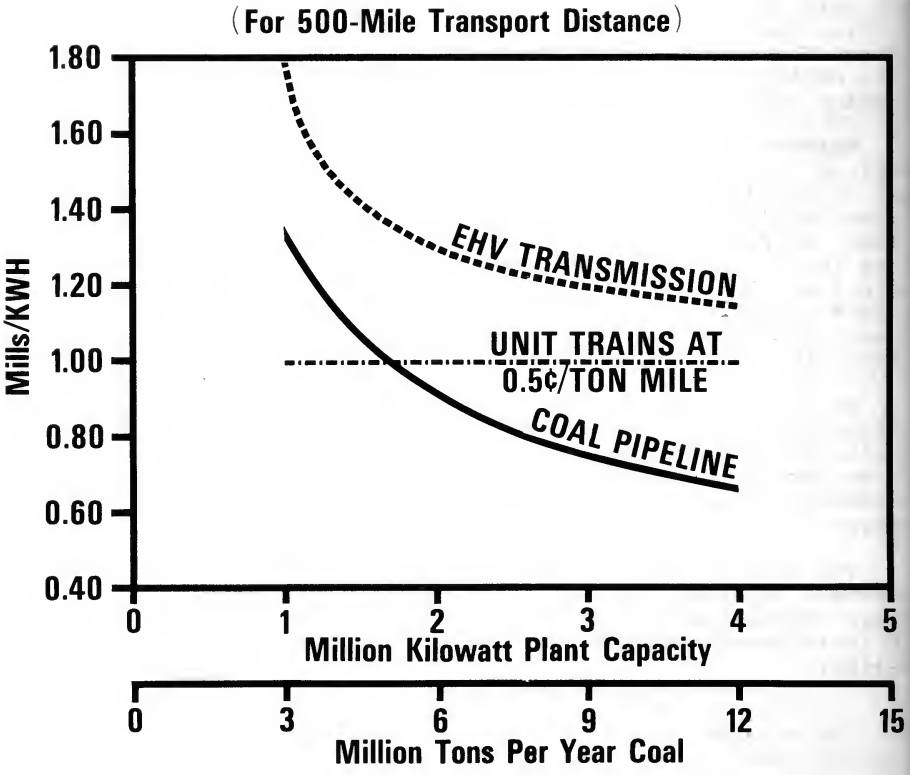


Figure 1

Comparison of Alternate Modes of Coal Energy Transmission

Figure 2

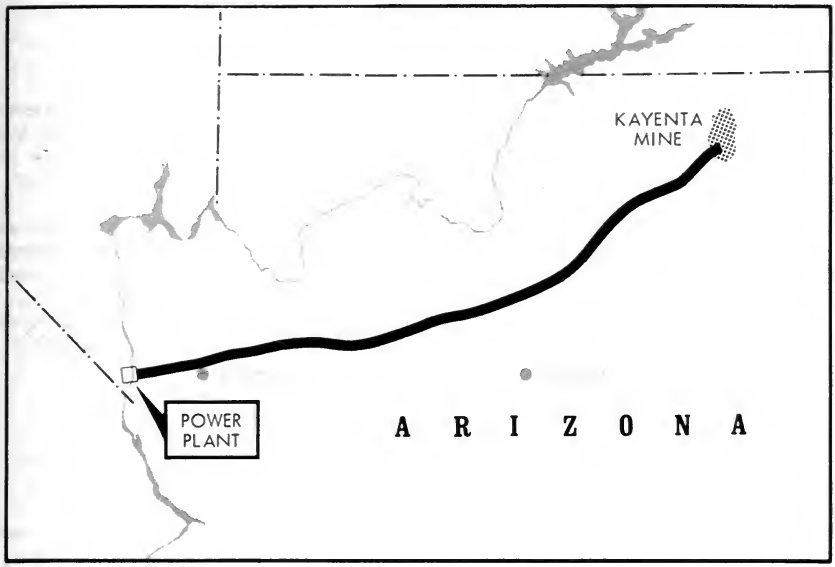
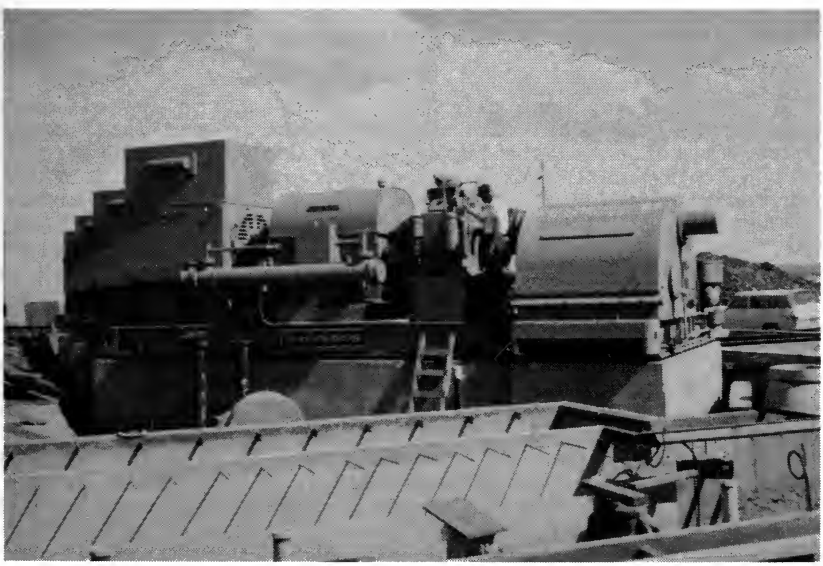


Figure 3



PANEL: REVIEW OF RESOURCES AND THEIR RELATION TO THE ENVIRONMENT

W. F. Clark

The next segment of this Symposium presents first, an overview of the basic resources as they are related to the subject of the Symposium, then presents a wide-ranging group of speakers or environmental considerations.

There undoubtedly is not a person in this audience who is not aware of the accelerating degradation of our nation's environment -- and of the whole world's environment. The topic is very much in the public press, on the TV commentaries and documentaries, and in the radio reports. We have all read of these problems of degradation, seen many of them, and undoubtedly contributed to some of them.

Out here in the Big Sky Country of Montana, we're still relatively free of the enormous degradation problems of the heavily populated areas and heavily industrialized areas. Yet even here, in and around this beautiful city and State, I can show you samples of all major types of degradation. We have petroleum pollution of water and air, filth (and offal) and sewage in drainage ditches, urban sprawl of grossly stupid nature, highways built without consideration of drainage or of other valid competitive land uses, land that illustrates the worst effects of strip mining, streams full of silt, phosphate plants poring out flourides, the effluents of smelters killing and poisoning vast areas, mine waters killing fish, tepee burners and the Hoerner-Waldorf paper mill blotting out the sun of our Garden City of Missoula, and power plants, like the new coal-burning Montana Power Company plant here in Billings, built -- out of stupidity or at least out of an utter lack of a sense of public responsibility -- right inside the tightest place in the Yellowstone valley.

The record of resource extractors and resource processors in relation to environmental degradation is not a good one. Yet they have but reflected the public attitudes, and have responded to the public demands. But a new era is upon us. The public is rapidly becoming aware of the degradation. It will soon demand that industry, agriculture, resource extractors, resource processors, land developers, and all other aspects of our massive economy fully recognize that a social cost of doing business is the prevention of the degradation of the environment.

We must, gentlemen, cultivate channels of communication, find avenues of action, develop solutions for problems, devise social, political, and economic structures to make it possible to implement those solutions, and, most importantly recognize that we're all in this together. We must cease drawing battle lines on every issue between opposing groups. There is middle ground, and we must find it. It is wrong and silly for the industrialists to view what they call conservationists as impractical, starry-eyed

Dr. Wilson F. Clark, Chairman, Division of Science and Mathematics, Eastern Montana College, Billings, Montana.

preservationists, totally unaware of economic, engineering, market, and financial factors. It is equally wrong and silly for the conservationists or (as they are now called) the environmentalists to view the industrialist, the extractor, the processor as beady-eyed exploiters who delight in environmental destruction. The road ahead is an obscure one. It can be found, but only if each one of us, each segment of our society and economy starts to recognize an individual responsibility towards the total environment.

The outstanding speakers in this section of the Symposium will shed light on many facets of these problems, and from several different viewpoints. I believe the session will prove to be most interesting.

MONTANA'S STRIPPABLE COAL RESOURCES

Robert E. Matson

INTRODUCTION

The knowledge of coal occurrence is not new to this area. Lewis and Clark, in their journals, upon reaching the confluence of the Yellowstone, or roche jaune as it was then known, described several strata of coal. Farther up the Missouri two days later, they described greater appearances of coal with beds as much as 6 feet thick. In addition, they described strata of burnt earth, on the same level of the coal.

It is now known that coal is one of Montana's most widespread and abundant resources. Various publications are availalbe estimating the coal reserves of Montana, both in terms of total reserves and strippable reserves.

RESERVE ESTIMATES

Estimates of the total reserves have been compiled by the U.S. Geological Survey, and the figure that is most used is 222 billion tons. This figure is a compilation and estimate based on work by U.S. Geological Survey geologists who mapped much of eastern Montana for the purpose of classifying lands and clarifying patents under the Homestead laws. Included in this estimate are coal beds as thin as 18 inches. A more recent estimate by the U.S. Geological Survey, which includes estimates of reserves in unmapped and unexplored areas, increases Montana's total reserve to 378 billion tons (Averitte, 1968).

Since 1950, attempts have been made to estimate the strippable coal resources in Montana. The first, in 1950-51, was by the engineering firm of Ford, Bacon, & Davis, contracted by the Corps of Engineers at the request of the U.S. Bureau of Mines. The title of the report, interesting enough, is "The Synthetic Liquid Fuel Potential of Montana" (1951).

Also in the early fifties the U.S. Geological Survey began evaluating strippable coal lands and published a series of reports covering several major areas of eastern Montana. An example of this kind of report is the one by Kepferle, entitled "Selected Deposits of Strippable Coal in Central Rosebud County, Montana" (1954).

These reports served as a basis for a detailed description of strippable coal reserves in eastern Montana, in 1965, by Paul Averitt of the U.S. Geological Survey. His report (published as Montana Bur. Mines and Geology Spec. Pub. 36) outlines 59 sites and estimates the total strippable reserves in these sites at 5.112 billion tons.

In 1968, Averitt, in U.S. Geol. Survey Bull. 1252-C, entitled "Stripping-Coal Resources of the United States", estimates the

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strippable coal resources of Montana at 15 billion tons.

The most recent report on strippable coal in Montana is U.S. Bur. Mines Prelim. Rept. 172, March 1969, by Ayler, Smith, and Deutman. This report, covering 37 deposits, delineates 12.7 billion tons of strippable coal. Although the estimate of total strippable coal reserves is not as large as those by Averitt and by the Montana Bureau of Mines and Geology, at present this is the most comprehensive description of strippable coal fields in Montana. The report includes a map of the strippable coal and 31 illustrations delineating the major coal fields. It is currently being revised and should be available in the near future.

MONTANA BUREAU OF MINES AND GEOLOGY PROGRAM

The efforts of the Montana Bureau of Mines and Geology began with the holding of the First Montana Coal Symposium in Butte and the subsequent organizing of the University System Coal Resources Research Council. Strippable coal evaluation began in 1965, after funds were appropriated to the Coal Council by the Legislature. The Bureau's program was devised to acquire accurate data on strippable coal deposits by surface mapping, core drilling, and core analysis, and to publicize the data. At the present time, after almost five years of coal-resource evaluation, the Montana Bureau of Mines and Geology estimates the total strippable coal reserves at about 17 billion tons. Although this is an increase over previous estimates and not based entirely on detailed mapping and drilling, it is still thought to be conservative.

Areas that have been evaluated by the Montana Bureau of Mines and Geology since 1965 include the Foster Creek coal field, the Broadus coal field, the Sand Creek field, Poker Jim-O'Dell Creek, Otter Creek, Sonnette, Sweeney-Snyder Creek, Pine Hills, Moorhead, McCone County, and smaller deposits on Cache Creek (Pl. 1 and Table 1). Of these areas, six were evaluated under cooperative field-reconnaissance mapping programs between the Montana Bureau of Mines and Geology and the Northern Pacific Railway Company.

Recently published reports on coal-field evaluation include Montana Bur. Mines and Geology Bull. 69, entitled "Strippable Coal Deposits on State Land, Powder River County", and Bull. 73, entitled "Geology and Coal Resources of the Foster Creek Coal Deposit, Eastern Montana". Two other reports on open file at the Bureau offices include "Strippable Coal in the Moorhead Coal Field" and "Preliminary Report on Strippable Coal in McCone County".

In 1969, the coal-resource evaluation work by the Montana Bureau of Mines and Geology was enhanced considerably as a result of a special appropriation by the State Legislature and a grant by the Office of Fuel Resources, Air Pollution Control Administration, Department of Health, Education, and Welfare. The purpose of the grant is to obtain reliable analyses of core samples, to obtain data on the state's low-sulfur coal reserves, and to make this information available through publication. Through this program, espected to run for four years, core drilling of all the known unleased strippable coal deposits will be completed and chemical characteristics of the coal determined. During this first year, 83 drill holes were completed in an area extending from Bearcreek in southwestern Powder River County west to the

"Big Bend" of the Rosebud in southeastern Big Horn County, and north to O'Dell Creek in southern Rosebud County.

In addition to an expanded field-evaluation program, cores are now being analyzed by the Montana Bureau of Mines and Geology. Proximate analyses, sulfur content, and Btu values will be determined for all cores taken. Future work includes ash fusibility tests, ash analyses, and continued work in low-temperature ashing and mineralogical determinations of composition of coal ash. So far, one masters thesis has been prepared on the mineralogy of the ash of the Pawnee coal bed in Powder River County, and another is under way. The purpose of the second thesis is to study the mineralogy of the ash of coal beds in the Moorhead field. Both have been sponsored and funded through a research grant by the Grand Forks Research Center, U.S. Bureau of Mines.

It has become apparent, after a few years experience in evaluation of strippable coal deposits, that the only sure way of getting reliable information is by drilling. In the U.S. Geological Survey reports of the early fifties, it was found that the reserve estimates based on outcrop measurement and some auger drilling were too conservative. This is not surprising, as few natural outcrops of coal can be observed. Invariably, the thicker coal seams have burned at their outcrop and extensive beds of clinker have been formed. Where outcrops are found, they are weathered and are likely to represent less than the actual thickness of the coal bed, as some of the original constituents of the coal have been lost.

The extensive burning of thick coal beds in eastern Montana, particularly in the subbituminous area south of the Yellowstone River, has destroyed much of the coal originally present, leaving masses of reddish brown clinker of "scoria", as it is termed locally.

The thickness and character of the clinker is roughly correlatable with the original thickness of the coal bed and can be used as a guide in coal exploration. Coal beds 30 feet in thickness generally produce a clinker zone 60 to 80 feet in thickness.

OCCURENCE OF COAL

All of the strippable coal resources in Montana occur in the Fort Union Formation of Paleocene age (Fig. 1 and Table 1). This formation extends continuously across eastern Montana into western North Dakota, northwestern South Dakota, and southeastern Saskatchewan, and is called the Fort Union coal region. Total coal reserves in the Fort Union region exceed 1.3 trillion tons (Averitt, 1968). Montana's share of coal in the Fort Union coal region is estimated at 215 billion tons, of which 128 billion is subbituminous coal and 87 billion tons is lignite (Averitt, 1965, p. 20).

Regardless of this total reserve, future producible reserves will probably be limited to coal that can be strip mined. In strip mining, costs are low because of the extensive mechanization, which results in greater productivity per man-shift. Furthermore, 90 percent or more of the coal is recovered.

COAL RANK AND QUALITY

Coal is classified by rank, which relates to its Btu value (British thermal unit; heat required to raise temperature of 1 pound of water from 60° to 61° F), and by quality, which relates to its purity (content of noncombustible matter and sulfur), and to how it burns (whether it tends to melt, burn as a block, or break up into small pieces).

Eastern Montana coal ranks as lignite and subbituminous, according to the American Society for Testing Materials (ASTM). Under the ASTM system, coal is ranked by its calorific value in Btu per pound on a moist mineral-matter-free basis, as follows:

Rank	Calorific value limits, Btu per pound
Subbituminous A	10,500 - 11,500
Subbituminous B	9,500 - 10,500
Subbituminous C	8,300 - 9,500
Lignite A	6,300 - 8,300
Lignite B	<6,300

Subbituminous coal and lignite do not have the Btu value of higher rank bituminous coal, but they are present in great abundance and are nonagglomerating and more chemically reactive than bituminous (Groff, 1968). The latter characteristic may be an advantage of considerable importance in the new technology of coal conversion.

The coal in eastern Montana increases progressively in rank from lignite at the North Dakota border through subbituminous C southwest of Miles City to subbituminous B in southern Rosebud County and southeastern Big Horn County. Table 2 compares coal analyses from three principal areas of strippable coal in eastern Montana.

Table 2. -- Typical coal analyses expressed in percent on the as-received basis.

Location	Savage	Colstrip	Decker
County	Richland	Rosebud	Big Horn
ASTM rank	Lignite	Sub C	Sub B
Proximate			
Moisture	38.6	23.1	21
Volatile matter	25.1	29.9	39
Fixed carbon	29.3	41.5	41
Ash	7.0	5.5	4
Ultimate			
Sulfur	0.9	0.7	0.39
Hydrogen	6.7	6.3	
Carbon	39.5	56.9	
Nitrogen	0.6	0.8	
Oxygen	45.3	31.8	
Ash	7.0	5.5	4.0
Btu/lb	6,520	8,800	9,720

National concern and action relative to reducing sulfur oxides and other pollutant gases from stack effluent in coal-fired power generation stations has focused attention on the use of Montana and other western coal. It has long been recognized that coal in the Rocky Mountain area is inherently lower in sulfur content than coals in central and eastern United States.

The bulk of the strippable coal in eastern Montana coal fields contains less than 1 percent total sulfur, as is indicated on Table 1. In many of the deposits the total sulfur content is less than 0.5 percent.

The relatively low sulfur content will have a far-reaching impact in utilization of the coal to supply out-of-state utility markets, particularly in the upper Midwest area, where it is in competition with coal of inherently higher sulfur content and higher mining cost.

A smaller factor in air pollution is the ash content of the coal and the relative abundance of soda (sodium) in the ash. Low-ash coals burn cleaner, thus promoting better boiler efficiency. Coal containing more ash and soda tends to stick to the furnace walls, reducing efficiency and requiring shutdown to clean the furnace. Montana subbituminous and lignite coals have moderate to low ash content. In boiler tests run by the Grand Forks Research Center, U.S. Bureau of Mines, it has been determined that both Colstrip and Savage coal are low-soda types. Other ash analyses now available indicate a greater range in soda content, indicating that some eastern Montana coal may cause moderate boiler fouling.

FUTURE OF COAL

When one looks at the quantity of coal in Montana and past production records, it is apparent that this resource has barely been scratched. The optimistic picture in coal today is not based on past production but on what will occur in the future.

The upward trend in coal production began in 1968 as large-scale strip mining was resumed at Colstrip. Western Energy Company, a subsidiary of the Montana Power Company, began supplying the company's new coal-fired steam electric generation plant at Billings. This development, though very important in the revitalization of the state's coal industry, was overshadowed by the opening of the Big Sky mine near Colstrip by Peabody Coal Company. Peabody won a contract to supply the Minnesota Power and Light Company plants at Cohasset, Minnesota. This was a major breakthrough, since it introduced to Montana unit-train transport of coal to an out-of-state market. It is anticipated that these markets will be expanded to reach major proportions by 1980.

Another factor which may prove to be of major significance in utility markets for Montana coal is in interties between the central states and the western states. Studies of the Steering Committee of the Department of the Interior have shown that significant savings can be achieved by transfer of power by E.H.V. (extra-high-voltage) to meeting peaking requirements between the two regions on a daily and seasonal basis. Large strategically placed mine-mouth generation plants would most efficiently be placed between the areas, or in Montana and Wyoming.

In estimating the future use of coal in supplying utilities, it is not anticipated that the population in Montana and surrounding areas will increase drastically. Therefore, any large increase will be due to out-of-state shipment and in supplying large mine-mouth generation plants.

Although a large amount of research has been conducted and is underway, it appears that conversion of coal either to synthetic liquid fuels or pipeline quality gas is still at least 10 years in the future. The costs of conversion are still higher than conventional petroleum products and natural gas.

By 1980 it is anticipated that at least one commercial coal conversion plant will be in operation. Possibly by the year 2000 there will be five such plants in operation.

Each coal conversion plant will require a very large capital investment on the order of $300 to $400 million, total coal reserves in the neighborhood of 400 million tons, and annual water supplies of about 30,000 acre-feet. Production will be in the vicinity of 100,000 barrels per day.

Coal use in conversion may total about 20 million tons in 1980 and could total about 100 million tons by the year 2000.

SUMMARY

Montana has tremendous quantities of easily recoverable strippable coal. The current estimate by the Montana Bureau of Mines and Geology of 17 billion tons is considered to be conservative. It does not, for example, include the strippable coal on the Northern Cheyenne and Crow Indian Reservations.

The program in coal resource evaluation by the Montana Bureau of Mines and Geology is intended to refine existing information and to provide new data on the quantity and quality of the state's strippable coal resources through field evaluation and by laboratory analyses.

There is an extremely optimistic picture in the future of coal in supplying utilities, both within the state and out of state, and in conversion.

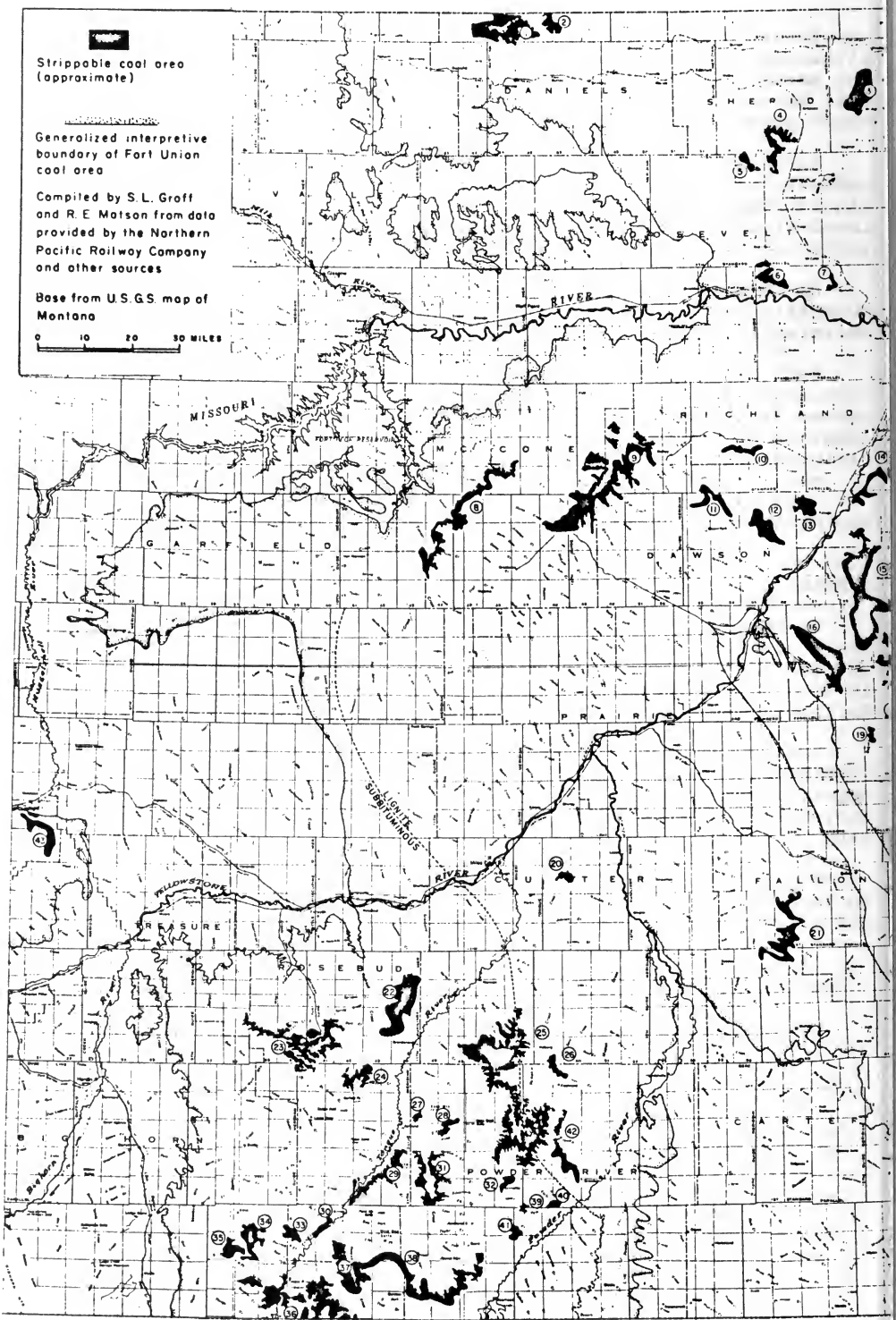
Strippable coal area (approximate)
Generalized interpretive boundary of Fort Union coal area
Compiled by S. L. Groff and R. E. Matson from data provided by the Northern Pacific Railway Company and other sources
Base from U.S.G.S. map of Montana
0 10 20 30 MILES
DANIELS
SHERIDAN
SEVEL
RIVER
MISSOURI
RICHLAND
MCCONE
GARFIELD
DAWSON
PRAIRIE
LIGNITE SUBBITUMINOUS
YELLOWSTONE
RIVER
CUSTER
FALLON
TREASURE
ROSEBUD
POWDER RIVER
CARTER
Powder River

FIGURE 1

EASTERN MONTANA SYMPOSIUM

TABLE 1

Strippable subbituminous and lignite coal fields, eastern Montana.

No. on Map	Name of Field	County	Coal Bed	Tickness in Feet	Estimated Reserves in Millions of Tons (R-rough; F-fair; G-good)	Typical analyses (as received basis)									
						Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Btu
1.	Carbert	Daniels	D & C	8	150 R	41.3	23.0	26.4	9.2	0.5	....	....	....	....	5,675
2.	Poplar River	Daniels	D	11	75 R	....	....	....	....	....	....	....	....	....	.....
3.	Coal Ridge	Sheridan	Coal Ridge	10	600 F	40.4	24.5	27.6	7.5	0.4	6.9	35.2	0.6	49.4	5,830
4.	Reserve	Sheridan		7	246 F	38.5	24.8	29.0	7.6	8.4	....	....	....	....	6,599
5.	Medicine Lake	Sheridan		9	58 F	37.0	26.3	29.5	7.2	1.0	....	....	....	....	6,870
6.	Fort Kipp	Roosevelt	Fort Peck Fort Kipp	5.3 8.5	278 G	42.8	25.7	26.9	4.6	0.2	7.2	36.2	0.8	51.2	6,110 .....
7.	Lanark	Roosevelt	Lanark Archer	....	100 G 38.1	 38.1	 25.5	 32.3	 4.1	 1.2					 6,724
8.	Weldon-Timber Ck.	McCone	S	8-20	724 G	30.5	27.7	35.9	5.9	0.6	....	....	....	....	7,660
9.	Redwater River	McCone-Richland	S	9-21	642 G	31.7	27.5	35.0	6.1	0.4	6.4	41.1	0.8	44.6	7,400
10.	Fox Lake	Richland	Pust	7-17	46 F	38.3	25.4	30.3	6.0	0.5	....	....	....	....	6,880
11.	N.F. 13-Mile Ck.	Dawson	Pust	10-43	225 F	38.3	25.4	30.3	6.0	0.5	....	....	....	....	6,880
12.	Burns Creek	Dawson	Pust	....	200 R	....	....	....	....	....	....	....	....	....	.....
13.	Breezy Flat	Richland-Dawson	Pust	9-25	200 F	38.6	25.1	29.3	7.0	0.9	6.7	39.5	0.6	45.3	6,520
14.	O'Brien-Alkalie Ck.	Richland	F, S, and H	....	150 R	....	....	....	....	....	....	....	....	....	.....
15.	Four Buttes-Smith Creek	Wibaux	G and C	5-20	400 R	37.9	26.4	26.1	9.6	1.0	....	....	....	....	6,140
16.	Griffith Creek Hodges	Dawson-Wibaux	A	10	90 R	....	....	....	....	....	....	....	....	....	.....
17.	Little Beaver	Wibaux	C	10-15	250 R	....	....	....	....	....	....	....	....	....	.....
18.	Beach-Wibaux	Wibaux	C	5-40	1,204 F	41.0	24.8	26.3	7.9	0.9	....	....	....	....	6,050
19.	Lamesteer	Wibaux	Harmon (?)	10	35 F	....	....	....	....	....	....	....	....	....	.....
20.	Pine Hills	Custer	Dominy E	6-19	100 G	30.8	27.3	33.7	8.2	0.8	6.2	43.9	0.7	40.4	7,220
21.	Lame-Jones	Fallon-Carter		6-10	150 R	38.7	27.0	25.1	9.2	0.3	....	....	....	....	6,020
*22.	Sweeney-Snyder	Rosebud	Terret	....	....	24.83	27.79	38.44	9.14	1.12	....	....	....	34.2	8,200
23.	Colstrip Castle Rock Arnells Creek	Rosebud	Rosebud, McKay	20-26	1,300 G	23.1	29.9	41.5	5.5	0.7	6.3	54.9	0.8	31.8	9,500
24.	Greenleaf Miller Creek	Rosebud	Rosebud Knoblock	4-12 3-21	....	....	....	....	....	....	....	....	....	....	....
*25.	Foster-Pumpkin Creek	Custer-Powder River	Knoblock-Terret Flowers-Goodale	....	....	31.6	26.8	35.4	6.2	0.2	6.3	46.2	0.7	40.5	7,630
*26.	Sand Creek	Custer-Powder River	Knoblock	....	....	31.1	27.8	32.8	8.3	0.3	6.5	43.1	0.6	41.2	7,220
27.	Cook Creek	Powder River	Sawyer	8-12	18 G	....	....	....	....	....	....	....	....	....	.....
28.	Home Creek	Powder River	Sawyer	8-9	41 G	....	....	....	....	....	....	....	....	....	.....
29.	Poker Jim O'Dell Creek	Rosebud	Knoblock	25	250 F	....	....	....	....	....	....	....	....	....	.....
30.	Birney	Rosebud	Knoblock Brewster-Arnold	40 20	200 R	....	....	....	....	....	....	....	....	....	....
31.	Otter Creek	Powder River	Knoblock	20-47	1,100 G	26.6	29.6	38.6	5.2	0.2	6.4	52.0	0.8	35.4	8,740
32.	Sonnette	Powder River	Pawnee	20	206 G	32.0	29.5	32.5	6.0	0.2	6.7	45.4	0.8	40.9	7,650
33.	Canyon Creek	Rosebud	Wall	30-64	80 R	....	....	....	....	....	....	....	....	....	.....
34.	Kirby	Big Horn	Anderson & Smith	20-30 20-30	200 R	....	....	....	....	....	....	....	....	....	....
35.	Bluffer	Big Horn	Anderson & Smith	....	80 R	....	....	....	....	....	....	....	....	....	.....
36.	Decker	Big Horn	Deitz	20-80	1,020 G	21.0	39.0	41.0	4.0	0.4	....	....	....	....	9,720
37.	Hanging Woman Creek	Big Horn	Deitz Anderson Smith	12 20-30 20-38	500 R .... 800 R	....	....	....	....	....	....	....	....	....	....
	Roland	Big Horn	Roland	6-15	300 R	....	....	....	....	....	....	....	....	....	.....
38.	Moorhead	Powder River	Canyon Deitz Anderson	17-25 6-11 14-30	1,500 F	23.4	32.3	40.4	3.9	0.2	6.1	52.7	1.1	35.6	8,920 ....
39.	Upper Cache Ck.	Powder River	Pawnee	20	40 G	32.0	29.5	32.5	6.0	0.2	6.7	45.4	0.8	40.9	7,650
40.	Lower Cache Ck.	Powder River	Broadus	12	10 G	33.5	28.3	32.2	6.0	0.4	....	....	....	....	7,290
41.	Fire Creek	Powder River	Pawnee	16-20	40 R	....	....	....	....	....	....	....	....	....	.....
*42.	Broadus	Powder River	Broadus	....	....	28.95	28.86	35.29	6.90	0.24	6.4	45.7	0.7	40.7	7,550
43.	Bull Mountain	Musselshell	Carpenter Creek	....	50 F	....	....	....	....	....	....	....	....	....	.....

	13,658
*Coal thickness and individual tonnage data cannot be released (Sweeney-Snyder, Foster-Pumpkin Creek, Sand Creek, Broadus)	3,350
TOTAL	17,008

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INDUSTRIAL WATER

Harold Aldrich

I am pleased to be here and to participate in a symposium of such immense importance to Montana's future well-being.

Montana must experience considerable economic expansion in the near future. Accomplishment lies in the development and use of the vast water, land, and coal resources of the State. The most precious resource -- excluding people -- is water, and the proper utilization of water is the "make-or-break" factor involved in Montana's economic growth challenge for the years ahead.

Projections that are a part of the Missouri River Basin surveys show considerable population growth during the next 50 years in the Yellowstone and Upper Missouri Subbasins. If the local economy, with its base firmly secured to agriculture, recreation, and minerals, develops as projected, the population of the area would grow to 1.7 million persons -- an increase of more than 1.1 million from the present.

Increase in demands for municipal and industrial water is projected at an even faster pace than that for population -- from a present use of 350,000 acre-feet to a whopping 2.8 million acre-feet annually. Recent events, which I will discuss later, lead me to believe that the Missouri River Basin Comprehensive Survey projections are on the conservative side.

This projected increase for industrial water way have a strange sound to Montanans. During the past 30 years most of us have grown accustomed to the loss of employment and economic opportunity in a predominately agricultural economy. It is a fact that our population's growth plodded along at only two-thirds of the growth rate of the remainder of the country.

According to Missouri River Basin surveys, development of the area economy as projected will increase annual municipal and rural domestic requirements from 70,000 to 260,000 acre-feet. Annual industrial demands, exclusive of the water requirements of coal-related industries, would increase from 180,000 to 440,000 acre-feet. The water demands of coal-related industries show tremendous growth. Thermal-electric power diversions would increase from 97,000 to over 1.3 million acre-feet, and coal hydrogenation from 0 to 750,000 acre-feet.

Before discussing the coal-related water requirements of eastern Montana, I also want you to know that there is other potential expansion in the area I am discussing.

One of our most favorably situated units for proposed industrial water service is Reichle Dam on the Big Hole River. This unit has the potential of providing a firm industrial water yield of 35,000 acre-feet.

Although no specific use has been defined for this water, the

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Harold Aldrich, Regional Director, Bureau of Reclamation, Billings, Montana.

most favorable alternatives appear to be in the forest products or mineral industries. Interest in industrial water service from the reservoir has recently been expressed by two large corporations.

Also currently underway is a study designed to evaluate the feasibility of municipal and industrial water service as an added part of the existing Lower Yellowstone Project. Municipal and industrial water demands for Sidney and the Holly Sugar Company are expected to increase fourfold in the next 50 years. Initial proposals for this unit call for the construction of a dam and reservoir on Lonetree Creek to which water would be pumped from the irrigation canal during the operating season. Later, water would be released from the reservoir providing a dependable supply throughout the year.

Returning to eastern Montana's coal -- a valuable resource that has lain relatively unexploited -- the time for its development and utilization may be near because of the Nation's rapidly expanding requirements.

Increasing demands for power and the development of extra-high-voltage power transmission enhances the potential economics of mine-mouth thermal-electric power generation from eastern Montana coalfields.

The Nation's accelerating demands for petroleum products is moving up from a present 12 million barrels per day to an expected consumption of 18 million barrels per day by 1980. The development of synthetic fuels from coal, oil shales, and tar sands may prove to be an economic source in helping to meet requirements.

The Missouri Basin Comprehensive Framework Studies indicate that water related to coal development will amount to more than 2 million acre-feet. Currently, the industry is using less than 100,000 acre-feet. This places future water required by the coal industry in the Yellowstone and Upper Missouri River Subbasins at more than 1.9 million acre-feet annually.

About 450,000 acre-feet of this requirement will develop in the Upper Missouri Subbasin. In this area, the need will be for thermal power production and can easily be satisfied from the main-stem Missouri River.

The situation becomes more difficult as we move into the Yellowstone Subbasin and the water-short regions of the Powder, Tongue, and Rosebud. Nearly 1.5 million acre-feet of water will be required in these areas. Certainly, requirements can be met. There is ample water -- but is isn't always in the right location at the right time. Additional water storage and delivery facilities will be needed. It appears that demand may be about equally divided -- 775,000 acre-feet in the Powder, Tongue, and Rosebud areas, and 720,000 acre-feet on the main stem of the Yellowstone.

Let's put the main stem of the Yellowstone aside for just a moment and discuss the tributary streams of the Bighorn, Rosebud, Tongue, and Powder.

Over on the Powder River, the Bureau is completing a report on the proposed Moorhead Unit. It appears that about 108,000 acre-feet of water for industrial use could be provided on an annual

basis. This would be divided about equally between Montana and Wyoming. On the Middle Fork of the Powder at the Hole-in-the-Wall site, Carter Oil is considering the construction of a reservoir which would provide about 25,000 acre-feet a year for industry. Reynolds Mining is developing a water supply at Lake DeSmet, and, according to the Montana Water Resources Board, it is investigating a site on the Tongue River that would provide about 60,000 acre-feet of water for industrial use.

Recent studies carried out by the Bureau on the Bighorn River have terminated in pleasing results concerning an industrial water supply. Our findings show that regulation of the river by the recently completed Yellowtail Dam southwest of Hardin, Montana, and by Boysen Dam located near Thermopolis, Wyoming, provides considerable water for use in addition to the authorized purposes of the units.

At this time, there is a total available supply of water from the Bighorn River for industrial use of 832,000 acre-feet -- 697,000 acre-feet of this water is from Yellowtail, and 135,000 is from Boysen. Of the water for sale from Yellowtail, 57,000 acre-feet has been reserved for future disposition, and 640,000 acre-feet -- 412,000 in Wyoming and 228,000 in Montana -- has been made available for immediate sale.

Keen interest has been displayed by energy companies in the water for sale from the Bighorn River.

You will recall a moment ago I said there was reason to believe the Missouri River Basin Comprehensive Studies were conservative. Well, it is because the interest of the energy companies has been so strong in seeking water supply sources that I can't help but feel the industrial growth of the area is going to exceed projections contained in the Comprehensive Study. We have even had an inquiry concerning the availability of an industrial water supply from Fort Peck Reservoir, and also from the reservoir behind Dickinson Dam in western North Dakota.

The Bureau is not in the synthetic fuel business, but it is well aware of the confidence existing among these companies. It is a fact that we have already executed option contracts or have received contracts and applications for 623,000 acre-feet of water available from the Bighorn River. The interest shown in obtaining Bighorn River water for industrial use, in connection with development of the coal resources of northeastern Wyoming and southeastern Montana, is -- to say the least -- amazing.

Just a short while ago, the Bureau was contemplating the start of a study concerning the delivery of water from Boysen Reservoir near Thermopolis, Wyoming, to the Powder River Basin. Before we even got underway, application for over 100,000 acre-feet of Boysen water for use somewhere around Gillette was received. As requests for industrial water increased and the varied locations of intended use broadened, we felt that the joint use of the conduits required to deliver water in the areas was becoming financially attractive.

The studies we are now beginning are of a reconnaissance nature and are scheduled for completion in the spring of 1972. The places of intended use for the water are widely dispersed, covering the Colstrip region, the Crow and Northern Cheyenne Indian reserva-

tions, the Powder River Valley in Montana, and the Lake DeSmet area in Wyoming. There will undoubtedly be other locations as explorations for sites to accommodate economical strip mining progress. Our investigations also include the delivery of water to municipalities such as Gillette, Sheridan, and Broadus.

Let's take a quick look at a pipeline route from Boysen Reservoir to Gillette. It would be about 200 miles long. For all practical purposes, Gillette is about the same elevation as the water surface in Boysen Reservoir. However, there is a 1,500-foot pumping lift required to get over the divide between the Bighorn and Powder Rivers. The delivery of 135,000 acre-feet of water per year to Gillette under this proposal would require a conduit 72 inches in diameter, which would carry 200 cubic-feet-per-second. About 69,000 kilowatts and over 580 million kilowatt-hours per year of electric energy would be needed for pumping power.

The Yellowtail to Gillette conduit would be about 190 miles long. Gillette lies about 1,000 feet above the inactive water level of Yellowtail Reservoir and about 1,500 feet above the Bighorn River. In addition, there are three divides to go over, around, or through. Making a rough guess at where tunnels will replace pumping plants, and assuming a 500-cubic-foot-per-second conduit, the total pumping head would be about 3,500 feet from the Bighorn River. This would require about 227,000 kilowatts and 1.9 billion kilowatt-hours of electrical energy. The 500-cubic-foot-per-second conduit would be about 96 inches in diameter. The 500 cubic-feet-per-second amounts to 350,000 acre-feet per year, and applications for use of water in the general area approximate that figure. The advantage of this line is that it could serve most of the coalfields.

A route from the Bighorn River near Hardin to Busby would be about 39 miles long and require a pumping head of about 1,300 feet.

A route from the Yellowstone River to Busby would be 66 miles long and require a pumping lift of about 2,000 feet. To get to Colstrip on this route requires 32 miles and a pumping lift of about 1,200 feet. This investigation involves hundreds of miles of buried pipe to operate the year around in a cold climate, long tunnels, high-head pumping plants, energy dissipaters, surge tanks, complicated hydraulic problems, pondage along conduits, terminal storage, transmission lines, switchyards, substations, and maybe even a powerplant.

All of the anticipated demands for water in Wyoming -- approximately 385,000 acre-feet -- required for use related to coal utilization can be more than satisfied. Sales of Bighorn River water, with delivery through the proposed pipeline now under investigation by the Bureau, and water from locally available sources, including proposals on the Powder and Tongue Rivers, will get the job done. However, these same sources will supply only about one-third of the water -- or about 363,000 acre-feet -- to meet eastern Montana's coal development requirement. This leaves a demand of more than 840,000 acre-feet to even begin realizing the conservative industrial potential projected in the Missouri River Basin Comprehensive Studies. Don't be alarmed -- this remaining demand is more than available, and in quantity, from the Yellowstone River.

The plentiful supply in the Yellowstone is not the full answer -- storage is required to firm up the flow of the river. Preliminary evaluations prepared by the Bureau of Reclamation show that standby storage of 1 acre-foot would firm up 10 acre-feet of demand on Yellowstone River flow. Using this ratio, our remaining main-stem industrial demand related to coal development could be firmed up with 84,000 acre-feet of storage. Storage capability of nearly 200,000 acre-feet could be made available at the two reservoirs -- Cedar Ridge and Buffalo Creek -- indicated on the map.

All of this development is not only possible, but quite probable. It can come about -- and quickly. Undoubtedly, it is going to require unified action between private industry and State and Federal entities. Money and cooperation will be prerequisites -- but it can be and should be undertaken.

LAND

Abstract of remarks by

Ted Schwinden

The analysis of land as a part of the resource base most often centers on statistics -- acres, forage, productivity. Related to environmental consideration, land still is treated in terms of wealth potential, population pressure, food demands, etc. These again are factors capable of measurement.

Land is characterized by subjective factors that are no less important in the never ending struggle to achieve optimum resource use.

Often overlooked is the high degree of emotional involvement in "land". The relationship between land and user is intimate. The disturbance of that relationship by transforming the primary use of the resource, or its appearance, can cause bitter antagonisms. The joint responsibility of government, of industry, and the public (who may be owner or part-user), is to recognize the explosive emotional context and to avoid inflaming already sensitive nerves.

A second characteristic of the land resource is the stringent demand it places on the user. A seemingly durable landscape in reality maybe a fragile resource. Best beneficial land use on a long run basis requires care; care administered with timeliness and thoroughness.

The alternatives for Montana need not be the mutually exclusive goals of "status quo" environment or unbridled industrialization and resource exploitation. Rather, Montana has the opportunity to act now -- to insure orderly growth and resource development while preserving an environment that a century hence may be called "great Heritage".

Ted Schwinden, Commissioner, Department of State Lands and Investments, Helena, Montana.

ENVIRONMENTAL CONSIDERATIONS

G. W. O'Connor

I am flattered to have been invited to participate in this Symposium, and particularly to have been permitted on the same panel with the distinguished associates who are with me today.

As one of your panelists, I approach the subject which we are assigned with certain trepidation because it may very well be one of those situations where you can't win. Any suggestions that might come from me concerning the requirements and responsibilities that we all have to protect our environmental heritage will be considered by the free-wheeling exploiter of the past to be too severe, too soon and too much. At the same time, the crusading preservationist will consider it to be entirely inadequate, too little and too late.

When we talk about environment, we're talking about people -- the action of people to land, people to air, people to water, people to animals, people to weather, and the action of people to each other. There is no form of enterprise or activity on this earth that does not affect the environment. We can accurately assert that almost every activity of man or beast, as well as every breeze or rainstorm, every cultivation of soil or harvesting of crops, including timber and minerals, affects the environment in which we live.

A great many of the changes which have taken place and have affected the environment are not bad. If we left it unaffected, fire would not have been put to use and the wheel should not have been invented.

Changes of the environment frequently seem desirable. None of us live in a completely natural environment. We have grass and flowers around our homes. We have taken literally thousands of acres of relatively unproductive, semi-arid and almost useless land and, by change, have made it highly productive, more attractive and a more inviting habitat for both man and other life.

Therefore, in our discussions, we cannot necessarily limit ourselves to the commonly accepted effects upon air, water and land when we consider coal as an energy resource. We must consider the total environment effects upon man's life by the use and also by the non-use of this resource. Certainly, it is a desirable environmental situation to have lights to brighten up the darkness, to have heat to combat the cold, and coolness to combat heat. It improves the environment of living also to have an unseen servant that operates more than 160 appliances around the home, to say nothing of the factories and the goods generated through the use of this servant, all of which accommodate our total environment.

Each of these things must be considered when we discuss energy conversion in a total approach to man and his environment. It is necessary to equate man's fundamental needs, along with

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George W. O'Conner, President, Montana Power Company, Butte, Montana.

maintaining an environment in its so-called natural state. So if we approach the conclusion that the development of our tremendous coal resources and the conversion of these resources into some useful energy are essential, we must accept the fact that there are going to be environmental changes by such activities.

We can and will solve the problems involved in the use of our coal, but I suggest that men and research can do more to solve problems than all of the laws that can be put on the books.

Along these same lines, there are those today who propose strict environmental standards which, in reality, can't be met; that is, without pushing our society back into the horse and buggy days. We must adopt standards which will allow us to use our most desirable fuels when viewed from an overall environmental view. Very recently, Dr. Thomas Sherwood of Massachusetts Institute of Technology and Co-Chairman of a study panel on sulphur oxides emissions of the National Academy of Sciences/National Academy of Engineering made this statement:

> "The States are starting to adopt standards the industry can't meet. In New Jersey, sale of coal with more than 1% sulphur is illegal. If such standards spread across the country, we may have to make a choice between power and clean air."

Our endeavors, therefore, should not be whether or not we use this vast resource in the Western part of the United States, but how we use it. We have two fundamental problems in the conversion of this resource to the betterment of man's environment. They are the consideration of the disposal of the waste products coming from that conversion and the displacement of land by reason of modern mining techniques. No one with anything like an enlightened approach believes that we should not strive to eliminate our waste by-products in the most efficient manner so that the minimum detrimental changes are made in the environment.

Likewise, we must reclaim the lands processed in the extraction of our energy resources so that they will perform a continuing, useful function, but it must be remembered that there is going to be some effect upon our environment by every one of these activities and, unless we approach the development of our resources realistically, we cannot obtain the greatest benefits from these changes.

Frequently what happens to be the panacea for the correction of our ills develops, in a short time, problems equally severe. A case in point is the concern of our biologists about the use of pesticides. Some of these insect destroyers were considered, just a few short years ago, to be the salvation of the agricultural industry. Now, there are those who consider them to be a very serious threat.

With the aid of medical science and mechanical technology, the life span has been increased from something like 20 years in primitive cultures to more than 70 years in modern society. However, this very act is precipitating a population increase which many consider to be disastrous, if not controlled. One wonders if the law of mechanics, which provides that "for every action there is an equal and opposite reaction," does not also apply to environmental management.

The key to the greatest advancement that mankind has made in any one country in the history of the world is the fact that, under our system, we employ a great many of the forces which have enabled us to develop our natural resources. It is my personal belief that future progress in the elimination of poverty in this country and throughout the world is directly dependent on how well we are able to develop new economic sources of energy. An important part of this development is going to be determined by our success in controlling the environmental effects associated with the production of this energy.

This nation and all of the world, at least based on present-day knowledge, are going to depend primarily upon nuclear and fossil fuels for energy supply in the future. Each of these fuels is not without its environmental control problems, but they must be realistically solved and they will be.

Montana is destined to play a very important part in this energy supply picture. This Symposium is developed around the fact that our State and those near us are blessed with valuable coal resources. Much of this coal is in thick beds close to the surface where it can easily be strip mined. It contains a very low sulphur content. This means it will minimize environmental effects due to air pollution. Current air pollution emission standards in some Midwest areas now require that coal such as this be blended with higher sulphur content Midwest coal if their environmental goals are to be met.

It is our challenge to develop this great resource with technologies that will give proper consideration to the problems of waste disposal and land reclamation. This is not a matter of setting rigid statutory standards which determine the shape to which the land must be returned. Each area may require some different approach in order to obtain the greatest degree of benefit from the reclamation process.

Though my own Company has operated a coal mine in eastern Montana for something over one year, we have not stripped or disturbed the surface over one ton of coal, but we have spent thousands of dollars up to date in a research program to determine what can best be done to get the greatest good from reclamation when we do start the stripping process.

Before mining operations were under way, we entered into a contract with the Agricultural Experiment Station at Montana State University for research and experiment work in the reclamation of mining areas. The program is now in its second year. It will continue for several more until we are able to determine the best types of plants, the correct planting and fertilizing techniques to produce useful lands, whether it be for agriculture, recreation, game refuge or whatever is the most promising.

I might mention something about eastern Montana lands which have been disturbed by past mining operations of years ago. What is left is not appealing or pleasing to the eye, and the aesthetics do not delight us but also, from firsthand experience, I can tell you that some of this mined-out area provides some of the finest protection for wildlife, in a country where there is not otherwise great protection, that it has been my fortune to see anywhere in this State. Deer run in abundance among the abandoned spoil piles. The rough topography resulting from the early mining

operation is one factor; another may be the dependable supply of water which accumulates in the open cuts. It is a refuge to which some of the upland game birds immediately go when hunted or disturbed and the topography defies their pursuit.

I submit to those who protest that nothing has been done in the past or no efforts have been made that there are countless examples of man having despoiled his environment and learned a harsh lesson which has prompted him to correct his course and take a different approach.

All of you of my vintage, at least, will recall that the breaking up of thousands of acres of sod land and the elements of weather combined to create in much of the prairie states what was referred to as the "Dust Bowl." This developed an environmental situation which drove people from their homes and farmers from their holdings. As a result of it, the strip farming and methods of controlling erosion were developed which have improved our agricultural methods immeasurably.

The overgrazing of literally millions of acres of native range grasses at one time threatened their total destruction. Under a more intelligent plan, a program of pasture rotation and controlled grazing, many acres which were once almost useless are returned to productive grazing areas.

I think I speak for the coal industry generally and the people who are involved in it when I say that we are anxious to develop, prior to the destruction of our environmental blessings, a program which will improve, if possible, the areas where we operate. We recognize that there are those who will demand reclamation laws which would prescribe the type of vegetation to be grown and the degree of contouring to be done, all of this even before any research or an examination has been made to establish the wisdom of such a course. It would be of little benefit to anyone to drill in a crop or to plant trees or vines or shrubs and grasses and turn up one crop failure after another simply because the law required it.

Our occupancy on this earth is going to be short; the earth will be around for a long time. We recognize that we are simply custodians of what God has given us. We aren't anxious to leave a heritage of beer cans, car bodies or despoiled land to those who will follow.

LAND RECLAMATION, AS VIEWED BY A COAL OPERATOR

T. A. Gwynn

"Improvement of our environment" has become a cause much like "motherhood". The increased awareness of the public concerning this subject makes it most unpopular for anyone to be involved in anything that seemingly is detrimental to our environment. And this awarement goes far beyond our biggest pollution problem in America -- the distribution of paper, abandoned automobiles, beer cans and other garbage by our enlightened society along every city, highway, trout stream, river and mountain in America. In fact,the greatest awarement comes because of the "sensational" reporting and writing in our various national communication media, wherein the same voting citizens who so generously distribute their refuse about the countryside are emotionally aroused and duped into transferring what is truly a national problem onto the shoulders of a few industries -- notably and particularly the mineral extraction industry.

In commencing my remarks today I would like to state first of all the position of Knife River Coal regarding reclamation and proposed legislation concerning reclamation:

1. Knife River firmly believes that mining companies have an obligation to return mined lands to the highest potential use to which they can be converted. As an industry we do have a problem. There is now the choice of coping with this problem on a voluntary basis or of ultimately doing it under restrictive government regulation. Government regulation can force inflexible standards on the industry that can only hurt coal and lignite producers.

2. Knife River firmly believes that the best job of reclamation, and certainly the most economical job of reclamation will be done by the mining companies themselves rather than by any government agency. In fact most of our present rehabilitation techniques have been developed by progressive coal mining companies. Any severance tax for the purpose of providing reclamation is opposed by Knife River as unnecessary and a more expensive way of doing the job -- hence oppresive to the industry.

3. Contrary to the opinion of some, Knife River believes that a firm Montana reclamation law is desirable and this law should be tailored according to the region and should be firm enough to meet any anticipated Federal reclamation law.

4. To gain some perspective of our environmental problem the public must first be reminded that not only is the air we breathe necessary for continuance of our life processes, but the mineral wealth of the earth is like-

Thomas A. Gwynn, Company Geologist, Montana-Dakota Utilities, Bismarck, North Dakota, and also Manager of Reclamation and Conservation for Knife River Coal Company, a subsidiary of MDU.

wise essential. Yet both are taken for granted. The need for lignite and coal in our present economy must be stressed. Power generation is increasing and the cost of power to the public as well as future income to the state will be affected by the tax burden imposed on this industry. While we encourage strict but constructive reclamation requirements, we urge that such controls not be unrealistic, punitive or restrictive to the point of stifling the industry in Montana, at a time when new sources of energy must be developed. The supply of minerals needed by our affluent (or should I say effluent) society is becoming increasingly critical. For instance, the present rate of population growth coupled with the technological explosion is increasing the consumption of minerals and energy at a fantastic rate. The daily consumption by our nation now makes the fabulous new Bell Creek oil field equivalent to less than one week's national oil supply. Robert Duncan of Kerr-McGee stated that during the next 32 years 7 or 8 times as much energy will be consumed by mankind as the total used since the time of Adam and Eve. The industry I represent today is growing at an even faster rate. The demand for electric power is doubling every ten years. As a matter of fact -- coal burned for power in North America is expected to approach 600 million tons per year by 1980, more than doubling the production over a period of only 15 years -- and to 800 million tons by 1985 per Hollis M. Toole, Assistant Secretary of the Interior.

5. As a company we fully favor cooperation between the company and various governmental agencies including but not limited to the Soil Conservation Service, Game and Fish Department, and others. Knife River opposes any effort to place control of reclamation under any single agency because every agency has special areas of interest, and we believe that reclamation properly will ultimately encompass many areas of interest, some of which are not necessarily in keeping with the aims of any one governmental agency. We had better realize now that no matter what type of reclamation is undertaken, we will not as an industry please everyone.

6. The scope of the problem is relatively small compared to the attention being given it. While we fully recognize the need for reclaiming mined lands, we believe it significant that Knife River Coal has been using approximately 10 acres a year since operations commenced in August, 1958, and total area mined to date is considerably less than a quarter section. Despite the impression given the public, reclamation has been conducted by the coal industry for more than 50 years. In the difficult areas mined in the northern Rocky Mountain and Great Plains states, often where vegetation will not grow even in the undisturbed lands, tens of thousands are being invested annually by mining companies to research a method of successful reclamation. In some areas successes follow -- in other areas only failure, but the companies keep trying.

With the above aims in mind I would like to state clearly that

during the last session of the Montana legislature, Knife River was in favor of strict legislation being enacted in Montana requiring that certain standards of reclamation be met. Specifically, we favored Senate Bill 179. Such a law was enacted in North Dakota in the last session of the legislature and, while we have not operated long under this law, experience over many years with a similar law can be observed in Illinois. Such regulation tends to satisfy the public and establishes a standard for all companies operating in the state. Inequalities are eliminated wherein one company gains a competitive advantage by conducting poor reclamation as compared to other companies. An adequate law cannot help but maintain state sovereignty in our industry, and early responsible action by operators and individual states cannot help but have some effect upon the speed with which the federal government enacts legislation. We as a company fully expect federal legislation to come, though it may be a few years hence. And we do not expect it to be in the form of a voluntary type of law comparable to the Montana or Colorado law. Accordingly we will not oppose future attempts in Montana to enact this type of legislation if realistic and drafted with the problems of the industry properly considered.

Knife River recognizes the unusual problems in reclamation of mined lands in Montana, having had several years experience in the Savage, Montana, area. Tens of thousands of trees have been planted and various legumes seeded, often with total failure but occasionally with surprising success. Successes have been sufficiently encouraging so that we have concluded that our Savage mines can ultimately be fully reclaimed to a useful purpose. To think that we can level the lands and eventually have fields of grass belly deep to a tall steer is unrealistic of course, but grazing lands or wildlife habitats are entirely within the realm of reason. I spent a day last week with several representatives of the North Dakota Wildlife Federation visiting mined areas. These men, mostly ranchers by profession, were openly impressed with the grazing potential of our reclaimed areas, though they still recommended that the areas be reserved for wildlife habitat. The rolling spoils, if properly planted can provide areas of protection and good forage in an area otherwise flat and open.

Our success with tree plantings has been spotty but we are finding increased encouragement with certain conifers as well as with experimental methods of planting employed by Mr. Hodder at MSU. Furthermore during 1969 about 15% of the Knife River Coal spoils banks in Montana were partially leveled, fertilized and seeded. A Klod-buster is now being used experimentally to help prepare and seed the slopes. Obviously the results will not be known for another year except for one tract of approximately 10 acres which was seeded in the spring of 1969. Despite a dry summer the stand of grass and clover on this tract is very encouraging.

As a result of experimentation we have concluded that substantial leveling and rolling can be done following mining. This does not mean that all the past arguments against leveling are now invalid, because there still seems to be little reason for leveling unless the planned usage for the land requires it. Leveling just to make the area flat is senseless, and may create new problems or eliminate desirable potential usages for the land. For instance, leveling clay soils results in compaction that reduces water retention capacity to the extent that the leveled area may remain barren indefinitely. To those who scoff at this I need

only refer to numerous publications and experiments in other states by state and federal agencies. In this country a trail created in the prairie by wild game, livestock, or the wagons of our pioneers, remain as indefinite evidence of the damage caused by compaction of the soil. Just a month ago I was on the clearly defined Oregon Trail, where wagons ceased to roll 100 years ago. On the other hand I was on a dragline three weeks ago as it opened a new pit, and at one point where a ramp had previously been located, subsequently filled with spoil material, the dragline rehandled spoil material two or three years old. The old spoils were saturated with moisture whereas the native soils adjacent thereto were dry, demonstrating the increased ability of spoils to collect and retain moisture improving ground water levels and reducing runoff.

Furthermore leveling can at times eliminate the benefits of water accumulation, which water has been a blessing to the stockmen in the Colstrip area, for instance. Ten days ago while flying over the area I was newly impressed by the substantial water that has accumulated in the old pits at Colstrip, said water being of good quality and of benefit to livestock and wildlife, and suitable for recreation including swimming and trout ponds.

Nevertheless, in answer to public pressure, Knife River Coal has adopted the practice of rolling and leveling each year at least as much acreage as has been disturbed, with leveling followed by fertilizing and seeding. Within a few years the company will have caught up on past mined areas, and new mined areas will be partially leveled immediately following mining. Then after further reclamation the results will come, but with 12 inches of rainfall we know that many years may be required before the evidence will satisfy the public.

Pollution is not a problem in our industry. I have found no acid waters in any of the areas mined for coal and lignite which I have visited in North Dakota and Montana. Montana just simply does not have the acid water and pollution problems present in Ohio, Kentucky and other midwestern states. This is partly because of the low rainfall rate which provides practically no runoff, and the type of mining which locally leaves depressions rather than cut hillsides, but in the Knife River mines it is also partly due to the program of eventually covering slack piles and not leaving potential acid-producing materials exposed.

Finally I would like to emphasize the point that I commented on previously in starting this report, namely that Knife River is very much opposed to any severance tax. It is a fact that none of the significant coal producing states to my knowledge have a severance tax. Montana has to stay competitive if its coal reserves are to be developed. Despite the presence of excellent coal reserves Montana is in competition with Wyoming, North Dakota and other states. The experience of Knife River Coal proves that mining companies can and will if properly motivated perform reclamation; and certainly no one can do it cheaper than the mining company with their equipment already on hand and their administrative offices already established. But the process of reclamation takes time -- and will not be accomplished overnight or even in three or four years.

So in conclusion I would again emphasize the stand of Knife

River regarding reclamation and legislation thereon:

1. We favor reclamation, and know that economics permit some leveling if a good purpose will be served by leveling. Reclamation must be a part of our every day mining operation and must be an anticipated expense. This reclamation must be the result of marrying the best technical assistance we can get to the hard economic facts of the coal mining business. This reclamation must be carried on with sensitivity to the needs of the area we are mining in and to the feelings of the residents of the area.

2. We insist that reclamation by the operator makes much better sense than does reclamation by any government agency. Accordingly we oppose any suggestion of a severance tax.

3. We believe that this is a right that should not be taken from the company.

4. We favor a firm law similar to the North Dakota law requiring companies to reclaim lands. Better policing of our own back yard and far-sighted positive support by the industry in drafting reasonable legislation can often head off the threat of punitive or confiscatory legislation.

5. We favor cooperation with government agencies, but not control by any given agency.

6. And finally, we feel that more credit is due the job being done by companies mining coal and lignite in Montana, and the research and experimentation that is underway and sponsored by these companies. The unfavorable publicity accorded the industry is generally out of proportion and often quite unfair or uninformed.

Individual concepts must be broadened and honestly cause each of us to recognize the view and values of others. Whether a member of the mining industry or a member of the public looking on, a further evaluation of the other's viewpoint will help. Certainly, as former Secretary Udall once said:

> "The need for a new national attitude toward our environment has grown until today it is an absolute necessity for human survival. Technology has stretched and magnified our natural resource potential in many areas ... But it cannot provide us with one square inch of additional planetary surface, nor do more than gloss over the mounting environmental insults to humanity.
>
> "It becomes increasingly apparent that runaway population, noise and psychological pressure of too-close living will eventually run us out of space and nervous energy even if food and minerals and fuels were never to flag."

This is the problem and the challenge our industry and our civilization faces.

CONSERVATION IN THE USE OF COAL

J. L. Grahl

Basin Electric Power Cooperative as a wholesale power supplier for rural electric cooperatives located in eight states of the Missouri Basin, including Montana, is presently operating the 216,000 KW lignite-fueled Leland Olds Station near Stanton, North Dakota. This first large lignite-fueled unit in the U.S. and Canada has been operating since January, 1966. It is fulfilling very successfully its purpose of a low-cost kilowatt-hour factory for the cooperatives.

Because it has a fuel cost of about 1.5 mills/kwh, it is a base load plant, and we burn about 1.2 million tons of lignite per year.

From the beginning, the Basin Electric membership and Board of Directors, as established policy, have tried to reduce the adverse effects on the environment of our plant operations.

However, given the present technology, there is no way of producing the thermal electric power our society requires without affecting our environment adversely. The plants fueled with coal and lignite produce waste heat and ashes, and result in the strip-mining of land. Atomic power plants discharge even larger amounts of heat and result in substantial quantities of radioactive wastes.

A power producer at present has no choice but to build one of the types of plants now available, despite its effects on the environment, but we can do our best to reduce these effects.

Basin Electric has been making such efforts. For example, we have attempted to do something about water pollution. When we started design of our plant, North Dakota had no anti-water pollution law and we could have dumped our ashes (about 60,000 tons per year) into the Missouri River as far as state law was concerned. We do not do that, but impound them in a lagoon and return clean, effluent water to the river. More significantly, we were the only industrial organization, to my knowledge, to support the enactment of the model anti-water pollution law by the North Dakota legislature in 1967.

Our plant does discharge waste heat into the Missouri River. However, at this stage of development along the River, we have been advised by the State environmental health officer that the heat discharged is probably beneficial because it keeps a stretch of the River open during the winter and thus increases oxygenation.

With respect to air pollution, power plants have a problem with the Western coals. Their low sulfur content is desirable because it reduces air pollution by oxides of sulfur, but electrostatic precipitators, designed to remove 96-99% of the fly ash from stack gas, apparently do not work well with low-sulfur ash.

James Grahl, General Manager, Basin Electric Power Cooperative, Bismarck, North Dakota.

Basin Electric is going to participate with a major equipment manufacturer and the U.S. Bureau of Mines laboratory in Grand Forks in a research program with a large pilot unit to try to develop improved techniques and equipment and more efficient ash removal by electrostatic precipitators when used with plants burning Western coals. The immediate objective will be an improved and more efficient electrostatic precipitator in our second generating unit, of 400,000 KW, to be built at the Leland Olds Station by 1974-75. This research is of especial importance, we believe, because enormous amounts of these Western coals are destined to be burned in power plants in the years ahead. We hope through this joint effort to help minimize the air pollution which this coming development otherwise will cause.

Basin Electric also advocated state legislation controlling air pollution, and such a law was enacted in 1969.

With respect to fly ash, Basin Electric has supported research on the uses of fly ash at the University of North Dakota for several years, by Dr. Oscar Manz. This research already has paid off. As the result of work by Dr. Manz and the North Dakota highway department, lignite fly ash was specificied last spring as an acceptable mineral filler for asphalt paving. Several thousand tons of Basin Electric fly ash were used in highway construction this summer, and we expect much more to be used in the future.

I believe we were the first power producer in the Missouri Basin voluntarily to require our coal supplier to grade the spoil banks so as to return them to the "contours of rolling countryside", and to participate with us in experimental plantings. The mining company estimates that the grading adds about 1.5 cents per ton to the price we pay for lignite. Out of an annual fuel bill of about $2 million, we pay about $17,000 for grading the spoil banks so that they look similar to the landscape before it was strip-mined. The planting of trees, shrubs and grasses is still experimental.

Consequently, we can say that spoil banks can be graded so that they are not eyesores, and are passable by vehicles as well as on foot, without unacceptable expense to the consumer of electricity.

Finally, we also have tried to make our power plant an attractive part of the landscape. How to do this puzzled us at first, as it seemed that any large industrial facility would stick out like a sore thumb in the open North Dakota prairie. However, it was suggested that the main feature of the landscape was the blue sky. We accordingly used shades of blue for the plant, and Consolidation Coal Company used a matching color scheme for its conveyors and crushing plant. This color scheme worked out just the way we hoped it would. My wife contributed the original suggestion, illustrating that it is sometimes worthwhile to talk about these problems at home.

I have reviewed Basin Electric's efforts in behalf of the environment not to brag but to illustrate that industry can do quite a bit to ameliorate its disturbing effects on the environment with a reasonable degree of effort and at acceptable expense, compared to the total costs of doing business. One reason for our efforts has been to demonstrate this fact, to encourage the relatively undeveloped states of the Missouri Basin to enact

regulatory legislation before the industrialization that is coming pollutes the air and water and ravages the landscape to the degree that has happened in other parts of the country.

Montana, with its enormous resources, should make sure it has legislation to require new industrial plants to minimize air and water pollution to the extent technically and economically feasible, and to do a reasonable amount of rehabilitation work on spoil banks. There is no use depending upon voluntary action. It is not reasonable to expect industry to do these things voluntarily, because they do cost money. In competitive enterprises, individual companies will not spend money to reduce damage to the environment when they know their competitors may not do so. If the law requires all to do so, however, then all must operate according to the same ground rules.

Basin Electric's experience is illustrative in this regard. We wanted to install an electrostatic precipitator in our first unit, to take out 96% of the fly ash instead of the 85% which our mechanical collector removes. However, our banker (REA) could not justify the additional investment because it was not required by either State or Federal law. As a consequence, our first unit has the less efficient equipment, as do two subsequent plants built by others.

In constract, when we included funds for an electrostatic precipitator in our loan estimate for our second unit (of 400,000 KW), the substantial additional cost was approved because it was evident by that time that State and Federal legislation would be enacted which probably would require this increased protection of the atmosphere.

Obviously, it is better and cheaper to install such equipment when a plant is built than to have to modify the plant later or else live with continuing pollution which could have been prevented.

Efforts to minimize adverse effects on the environment are extremely important, but they nevertheless represent a "band-aid" approach compared to what needs to be done if our environment is to be protected to the extent necessary.

To protect effectively our resources and our environment, in view of the great expansion in coal-fired power production in this region in the next twenty years, we need to develop a technology deliberately designed to conserve our fuel supplies, in the case of generating plants, and to minimize the damage done to our air, land and water.

The present technology is not designed for these purposes. For example, coal-burning power plants waste about 65-70% of the heat in the coal. This waste heat has no place to go except into the environment, into bodies of water and the air. There is little at present that a power producer can do about this because it is the only type of plant available. The nuclear-powered plants are even worse and waste a much larger percentage of the heat of fission, again discharging it to the environment.

So one program urgently needed is the development of far more efficient and less primitive methods of converting coal to electric energy. The process termed magneto-hydro-dynamics has a theore-

tical efficiency of 65%, about twice that of present coal-fired plants, and the solid fuel cell has a theoretical efficiency of about 80%. If we could build power plants with 60-70% efficiency, we then would have to mine only half as much coal to get the same amount of electricity, strip only half as much land, produce only half as much ashes, and discharge to the air and water only half as much waste heat as we do with our present technology.

Such a development would do more to protect the environment than any alternative program. It also would save billions of tons of irreplaceable coal resources.

A second basic step is to find ways to reach more rational judgments about what we use our resources for. At present, the nations of the world devote much of their resources to military purposes. They are providing themselves with weapons of annihilation at a cost of almost 200 billion dollars per year. This annual expenditure represents a huge non-productive consumption of natural resources, and a great deal of air pollution, water pollution, strip mining and other side benefits of industrial and military activity. Man could reduce damage to his environment enormously just be deciding that, with weapons on hand more than sufficient to destroy civilization, production for military purposes can be sharply reduced.

Without water, and the Earth's thin layer of topsoil and thin envelope of air, human life could not survive. Our technological society could not exist without continuing supplies of minerals and chemicals. As far as we know, Earth is the only planet in the Universe on which life is possible.

Our natural resources therefore are precious beyond measuring if we place special value on human life. Since society often places a very low value on human life, it is not surprising that we also have been incredibly unintelligent in selecting the purposes for which we expend our natural resources.

Although organizations like ours should continue to support good conservation practices, we face the fact that our activities in the end will be woefully inadequate unless mankind soon resolves to decide far more wisely and rationally the major purposes for which our resources are used, and to develop technologies for using them far less wastefully.

COAL INDUSTRY AT WHAT PRICE? A RANCHER'S VIEW

W. D. McRae

I would first like to thank Governor Anderson and the Montana Congressional Delegation for inviting me to speak at this Coal Symposium.

Being a rancher I don't know too much about the coal business, but I do feel qualified to shed a little light on what effect coal mining has had, and can in the future have on the Agricultural Industry. Needless to say, my research staff and speech writers at home on the ranch leave a little to be desired, so perhaps what I have to say can only be recommended by my sincerity.

We are all looking to the future to see how the development of coal will affect each of us, our industries, our state, and our nation. But let us look into the future with the past in mind. Let us consider the depredations of mining in the past when we consider the prospects of mining in the future. President Teddy Roosevelt once said: "To skin and exhaust the land instead of using it so as to increase its usefulness will result in undermining in the days of our children the very prosperity which we ought by right to hand down to them." Former Secretary of the Interior Stewart Udall had this to say: A ... lack of concern accompanied much of the mining for the minerals that have played such an important role in the development of our economy. It was, and still is, accepted practice to mine as cheaply as possible the deposits that are most accessible and provide the greatest profit to the producer. This preoccupation with short-term social costs involved -- the silted streams, the acid-laden waters, and the wasteland left by surface mining. Thus, valuable mineral resources have already been lost and several million acres of productive land and waters have been left derelict. Today, however, our national sense of values and attitudes is changing; so are our knowledge and technical skills. We are an affluent society; but we can no longer tolerate (or afford) either prodigal waste of natural resources or cumulative degradation of our environment."

The coal that is being mined at both the Western Energy Co. mine, and The Peabody Coal Co. mine is on surface that was formerly part of the ranch on which I was raised. I have seen the "before and after" of strip mining and its relationship to the livestock and farming industries. From my experience, strip mining and any agricultural endeavor are completely incompatable. Strip mining as practiced in the past has completely destroyed the productivity of the land for agricultural crop and livestock purposes, it has also destroyed the land's productivity for wildlife and game, and has perhaps even more significantly, and importantly destroyed the natural beauty of the land.

There is a myth about my part of the state that has it fixed in the minds of many people as a semi-desert, with endless flats barren, and treeless; broken only by an occasional bad-land, gumbo butte. The impression is that this is a land so devoid of

Wallace D. McRae, Rocker Six Cattle Company, Forsyth, Montana.

beauty and productivity that it is only fit for cactus, cowboys, and catfish. And all three of these rather undesirable species wish that they could live somewhere else.

In reality this is a beautiful, productive land, with an abundance of timber, live streams, (quite a few with trout in them) and unsurpassed rugged, western beauty. The desert myth can not stand up to the fact that there was a timber sale in Rosebud County this year for five-million board feet of timber; or that my country is a hunters paradise for deer, antelope, pheasants, grouse, turkeys and even an occasional elk or black bear; or that my country is the most economical area of the state in which to run a cow.

I am well aware that Montana is in search of new industry, preferably "clean" industry. Since I believe that Agriculture is a "clean" industry that utilizes a constantly renewing resource to produce its products, I question the advisability of eliminating even a portion of this industry of farming and ranching.

How much of our state are we willing to sacrifice for the sake of industrial development? Are we willing to write off one ranching operation? One county? Or the entire southeastern part of the state? I feel that one destroyed acre in the state of Montana is one acre too many. Montana has already had 26,920 acres disturbed by strip and surface mining. Some of this has been reclaimed, but there are over 19,500 acres in the state in need of reclamation according to the U.S. Department of Interior.

Coal mining, no matter how you may look at it, is not a clean industry. Neither in the past has it been a stable industry. It leaves behind a path of destruction that fouls the land. Its use, in the past, at the present, and even though advances have been made as reported at this symposium, I fear that in the future it will continue to foul our air and water.

I have seen millions of dollars worth of coal leave my area with little of it remaining in the area, or even the state. I have seen thousands of acres of productive land destroyed with only token reclamation attempted to repair this damage. I have seen people exploited, just as the land was exploited. These people left the area and the state with little evidence remaining to remind us that they were even ever here, save for the "spoil-bank" memorials that they erected in dedication to "King Coal." Of the twenty-two graduates of my highschool class only myself, and one other rancher are still living in Rosebud County.

My wife is from Pennsylvania and in that state I have seen the results of encouraging industry to come into a state. That once beautiful section of the United States has been exploited to an extent that it may never recover its once beautiful, and healthful environment. We can be thankful that we have the time to prevent, rather than repair, the damage and exploitation that occurred there. After a visit to Pennsylvania my wife and I come home to Montana convinced that the biggest asset we have in Montana is our lack of industry. Far from solving Pennsylvania's problems, financial or otherwise, industry has added to, and compounded them.

Abraham Lincoln had some advice for us all. He said: "I like to see a man proud of the place in which he lives. I like

to see a man live so that his place will be proud of him." I don't see how a man's place can be proud of him, or he proud of his place if he destroys its future productivity, its natural beauty, and deteriorates its environment in his quest for monetary gain.

President Lyndon B. Johnson had this to say: "The science that has increased our abundance can find ways to restore and renew an environment equal to our needs. The time is ripe to set forth a creed to preserve our natural heritage -- principles which men and women of good will, will support in order to assure the beauty and bounty of their land. Conservation is ethically sound. It is rooted in our love of the land, our respect for the rights of others, our devotion to the rule of law. Let us proclaim a creed to preserve our natural heritage with rights and the duties to respect those rights:

> The right to clean water -- and the duty not to pollute it.
>
> The right to clean air -- and the duty not to befoul it.
>
> The right to surroundings reasonably free from man-made ugliness -- and the duty not to blight it.
>
> The right of easy access to places of beauty and tranquility where every family can find recreation and refreshment -- and the duty to preserve such places clean and unspoiled.
>
> The right to enjoy plants and animals in their natural habitats -- and the duty not to eliminate them from the face of the earth.

These rights assert that no person, or company, or Government has a right in this day and age to pollute, to abuse resources, or to waste our common heritage. The work to achieve these rights will not be easy. It cannot be completed in a year or five years. But there will never be a better time to begin."

If Montana must have new industry in the state, let us assure ourselves and this new industry that we will not welcome it at the expense of our clean air, water and land, nor at the expense of any other industries, nor at the expense of our natural beauty, and animal populations, both domestic and wild.

ENVIRONMENT AND ECONOMICS GO HAND IN HAND

Gordon McGowan

The two topics I wish to discuss briefly this morning are environment and economics. I am a firm believer that you cannot consider or expand on one without considering the other. First preference makes no difference. A junior dictionary defines environment as surrounding things, conditions or influences giving as an example: a child's character is greatly influenced by his home environment.

I am sure we have all known of circumstances of how some wealthy families hopes were shattered as they turn young men and women out to face the world problems without the knowledge or ability to cope with other people, and face inability to master responsibilities. Many go through life unable to find their proper places in our society. By the same token, families of meager means have young men and women facing fear and insecurity, worry from lack of food, clothing, and many other necessities of life. Many in their tender years have had to accept too much responsibility. Both examples are not good in any society.

The very word "environment" has turned out to be a strange sound with many different meanings to many people. I dare say it could mean something different to every person in this room. It depends upon your background, method of making your living, the particular part of a state or a nation you live in. To some it means clean air -- to others clean water -- to the wage earner a good hourly wage -- to the lumbering man, lots of good trees and easy to obtain -- to the miner, a high grade of ore material that contains a good price per ounce -- according to our present standards -- to the strip coal miner, a thick vein with very little over-burden and a high quality.

To the farmer or grain grower, a price for wheat of at least $2.50 per bushel and $2.50 per hundred for barley. To the cattlemen, a much needed increase for price of calves and finished beef; perhaps 40¢ for calves and 30¢ for the finished beef.

To the fisherman, everytime he lost a big fish the next one he pulled out would be much larger.

To the camper and water skier, a nice clean campground and many lakes in every direction.

To the car dealer and implement dealer, a situation leading to people standing in line waiting to buy or purchase what they have before the new models begin to appear.

Environment to me today, I believe, would be a road that I could drive to Great Falls or Fort Benton on without beating my car to death when they are dry or sinking down from mud when wet. This story could go on and on and I'm sure the meaning of this word will take on some new changes in the not-too-distant future.

It has come a long way since 1928 when to many people it

Senator Gordon McGowan, Highwood, Montana.

meant "a chicken in every pot and two cars in every garage."

The same dictionary defines "economics" as: The science of production, distribution, and consumption of wealth. Economics deals with the material welfare of mankind and studies the problems of capital, labor, wages, prices, tariff, taxes, etc.

A philosophy was instilled in me 25 years ago that conservation is a wise use of resources for the betterment of mankind and generations to come. At this time, I can see no good logical reason to change that belief. Montana has been hamstrung for orderly resource development by individuals, organizations, businesses and others that have refused to look at the benefits to be derived for all of Montana, instead of their own selfish interests. Toward this development goal, I feel, all responsible people, organizations, divisions of government, political parties must embark. If this is not accomplished, we are fast approaching a dead-end street and I hasten to add a street of no return.

Montana is a state of vast natural resources that needs development to improve the economics of our state. No one and I mean no one should get the mistaken idea that they may slip in the back door and rape these God given gifts. Mining and exploration of can be improved on as well as the harvesting of lumber. Reasonable men can work out the details of improved resource development bearing in mind we have a state to operate. Trying to pass legislation that is too restrictive is as bad as no restrictions.

I would briefly like to cite some of our economic problems.

The 1967 State Legislature appropriated $124,800,000 for state operations not including, of course, federal funds available.

1969 -- $161,500,000 was appropriated. This is an increase of $36,700,000 for a two-year period.

Evidence is coming that a request will be made of the 1971 Legislature for around $200,000,000. I predict or hazard a guess that much trimming will be in order for many of the increase requests.

To plan and start some wise resource developments now could well be a key to our future needs.

The increase of $36,700,000 I mentioned was used as follows:

General Government	Increased	39.3%
Health and Welfare	"	34.2%
Education	"	27.2%
Custodial Institutions	"	31.0%
University System	"	25.0%
Vocational Education	"	294.4%
Executive Branch	"	111.0%

These increases were needed and long overdue to get our house in order.

Agriculture alone in Montana contributes in normal years $600,000,000 to our economy. In the figures just used, agriculture and funds for resource development took a 1.9% cut during this same period.

Resource development must have some new funds in 1971.

The reason, I believe, that these increases I mentioned passed in 1969 came about only because of organizations, alumni, agencies and individuals were working for them. The largest business -- agriculture -- received practically no consideration because of so many farm organizations thinking it better to continue opposing each other instead of uniting as they recently have done and are now working for betterment in the agricultural field.

Up to this point, at least, no one has arrived at a resource proposal development that has not stirred up a hornet's nest. The fact is -- Montana is desperately searching for new sources of revenue to operate our great state and provide the type of education, improved institutions, better highways and many, many more sources demanding so much of their government today.

Perhaps in my opening remarks I should have used 20 seconds and said any way you cut the pie you cannot separate environment and economics and sat down.

Again, I repeat, any way you cut the pie, you cannot separate environment from economics and now sit down.

COAL USE AND AIR POLLUTION

B. F. Wake

Good morning! It is a pleasure to have been invited to speak at this important conference and share the time with so many knowledgeable people and experts in this area. The calling of this symposium has stirred a great deal of excitement some of which is similar to that generated by a gold rush and others by the specter that coal almost invariably brings to mind tattered gray buildings, overshadowed by the big, belching smoke stack emitting foul smelling fumes, soot and flyash.

There was a time when the tall stack was a symbol of progress and hope. Today the dirty stack is a monument to decay or poor planning supported often times by an arrogant refusal to acknowledge the demands of a new day.

It's incredible that some influential persons require dead bodies for proof that air pollution is harmful. This may be in the form of animals, plants or even people it would seem. While it is true that the causal relationships have not been proven beyond any shadow of a doubt, in all cases, this is a legal metaphor that is misleading. "In law, the suspect is innocent until his guilt has been proved by any reasonable doubt. In the protection of human health such absolute proof often comes too late. To wait for it is to invite disaster, or at least to suffer unnecessarily through long periods of time. Many years ago before anyone had seen a germ or positively identified a single causitive agent of epidemic diseases, farsighted leaders observed the association between epidemic and filth. Wherever there had been sufficient foresight to act on circumstantial evidence they made striking progress. Cleaning up the city filth resulted in better health. It was only years later that they found out why."[1]

There being no doubt in my mind that the particulate portion of the air pollutants injected into the atmosphere from power plants, or any other coal burning installation, can be controlled adequately with equipment and procedures currently available and ready for use and being used, I am going to direct most of my discussion toward the tall stack as an air pollution "management" device for sulfur oxides and oxides of nitrogen. I have purposely said "management" device because this device is not a "control" device.

The policy of the Division of Air Pollution Control of the State of Montana, and I would hope to be that of my Board also -- and I believe that it is -- is as follows: The tall stack is never acceptable in lieu of, but only in addition to, control procedures. In other words, the "tall stack should regarded conservatively as an interim or partial solution to the pollution problems of power plants"[2] and other coal burning installations. "Although the usefulness of tall stacks in reducing gaseous pollutants in the vicinity of a plant is granted, the tall stack alone does not reduce in any manner the total pollution added to the atmosphere. Other means must be found to prevent overburdening

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the atmosphere with pollution, particularly under certain meteorological conditions. Data show that the tall stack does not prevent all emissions from reaching the ground. Under a variety of meteorological conditions, including precipitation, pollution from tall stacks may result in significant concentrations at ground level." "On the basis of TVA experience one may conclude that significant surface concentrations are attributable to emissions from tall stacks in the presence of light winds and limited mixing layers."[3]

The limited usefulness of the tall stack is supported further in the publication, Control Techniques for Sulfur Oxides published by the Department of HEW in January of this year: "Although a stack of any height usually reduces the ground level concentration it does not provide a reduction in the amount of material released in the atmosphere, nor does it preclude a significant concentration at ground level under all meterological conditions. The effectiveness of stacks may in some instances be limited by unfavorable terrain. The possibility of overloading the atmosphere by sheer size of the installation presents an unanswered question as to the adequacy of even very tall stacks."[4]

While I mentioned at the beginning that the technology for the control of particulates is well established. I could not dismiss the question altogether as there are some problems associated with any particulate removal program. "The trend has been to replace mechanical collectors with electrostatic precipitators alone or combined with a mechanical collector to achieve collection efficiencies of 97 and 99% or higher. The guaranteed flyash collection of new precipitators has risen from 96% in 1940 to more than 99% today. Almost all specifications for a new power plant electrostatic precipitators today call for collection efficiencies of 99% and up. The use of low sulfur coal can create a problem in that the flyash particles are more resistant to electric charge than those from higher sulfur coal at the normal operating temperature of the precipitator of 270° to 300°F. New York City will require by 1971 at the latest that all coals in the city contain no more than 1% sulfur. The effect will be to reduce the efficiency of power plant precipitators used there from 99 to 98% and new equipment will have to be added to counteract the effect at 0.5% sulfur, precipitation efficiency can drop to as low as 50% and it is not always possible to add new equipment. At higher operating temperatures, low sulfur coal becomes less troublesome. The first large precipitator in the United States to operate at higher temperatures was installed at a 1000 megawatt coal and oil fired unit in New York City. Efficiencies of more than 99.6% have been achieved at operating temperatures of 580 to 610°F when firing coal, whose sulfur content has essentially no effect on the efficiency."[5]

While these efficiencies seem quite high, there are reports that the global level of airborne particulates is rising. It is also reported that the mean global temperatures has been falling in recent years. It is recognized that other factors can also affect mean global temperature, "but the fact remains that particulate matter generated by man could be contributing to important geophysical phenomena."[6]

"The technological capabilities to collect flyash has shown a consistent trend upward. The average efficiency of collectors being specified today will be units that will be in service in the

next two to three years in the range of 98 to 99%. There is every reason to expect that this trend will continue. Fundamental research in electrostatic precipitation is now focused particularly on the collection efficiency region above 99%. Projections on particulate emissions from utilities in the next 30 to 35 years indicate a substantial decline in spite of the anticipated increase in the total coal utilization and boiler emissions. In spite of this projected decrease in total particulate emissions, increases are anticipated in emissions of submicron particulate matter, and these very small particulates may be found to be of particular significance in regard to health effects and in regard to possible long term climate effects."[7]

Nothing has been said up to this time, in my discussion, about air pollution from burning waste piles. Experience in other parts of the country with this problem has been most unsatisfactory. It is just simply unthinkable to me that air pollution from this source should be permitted -- to any degree.

CONCLUSIONS

Coal burning by conventional means can cause serious air pollution problems.

Coal burning does not need to cause problems.

Coal burning by any means must not be allowed to cause problems because it is unnecessary. Economics does not justify acceptance of the problem.

RECOMMENDATIONS

1. That the environment shall not be allowed to be marketed away by the economists.

2. That all new sources of contamination no matter where located in the state, shall be controlled in keeping with the most advanced state of the art. (Such a policy prevents, at the outset, the inclination to use air quality standards as a license to pollute.)

3. That any pollution source for which immediate control procedures are not yet developed, shall provide sufficient space in the plant area and sufficient money to include such procedures as soon as they become ready.

4. That burning waste piles, shall be prohibited completely and for all time.

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THE NEED FOR COAL LANDS SALVAGE ARCHAEOLOGY

Stuart W. Conner

Archaeological remains, like hydrocarbon supplies, are limited and unregenerative resources. The study of prehistoric archaeology originated a century ago. There then existed as many prehistoric sites as there ever would be. Since that time archaeologists, artifact collectors, reservoir construction, cities, highway and building construction, cultivation of the land, and open pit mining have greatly reduced the number of sites remaining available for scientific study. No new prehistoric sites have been generated, nor, obviously, can this occur in the future.

Archaeology is a branch of anthropology, which is the broad study of man. Archaeologists study the remains of prehistoric man's material culture. In the Montana-Wyoming-Dakota area these remains are found where prehistoric Indians lived, killed animals for food, clothing and shelter, had their rites, painted drawings on stone, buried their dead, quarried stone for their tools, and left other durable evidences of their life ways. Archaeology is a study of our precursors utilizing scientific methods of excavation, recording and analysis.

The cultural considerations of the study of prehistoric man are sufficient reason to require that archaeological sites be recorded by archaeologists before they are destroyed in the search for other resources. However, there are benefits to be derived from such research other than purely historical.

With the aid of sister sciences archaeologists have produced information which may be of great value to future generations of man. One example is the evidence of pronounced prehistoric climatic fluctuations in the American west which is under study by archaeologists, pleistocene geologists, glaciologists, palynogists, atmospheric physicists, dendrochronologists, soil scientists and others. This and similar studies are not merely abstract exercises. They are focused on how man was affected by climatic fluctuations. They may produce information useful in forecasting future cycles of climate fluctuation. The one indispensible source of evidence for this research is the archaeological site.

The coal lands of the plains of southern Montana, northern Wyoming and western Dakota have never been the subject of a methodical archaeological investigation. A few sites have been excavated by archaeologists. Many have been looted by artifact collectors. Enough is known to deduce that these buffalo plains were occupied by prehistoric Indians for several thousand years; that there is every reason to anticipate that many hundred archaeological sites of varying importance from inconsequential to major are located in the coal lands; that if the sites are not first scientifically examined, the coal stripping will result in a devastating and permanent loss to our potential knowledge of prehistoric man and paleoclimates on the Northwestern Plains.

If the archaeological investigation does not preceed the coal

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mining, perhaps the greatest loss will be information concerning climatic fluctuations. To properly date these cycles and to ascertain their intensity it is necessary that most of the raw data be collected from archaeological sites which were occupied by prehistoric people intermittently for many millennia.

There is perhaps no more important place in the United States than the Montana-Wyoming-Dakota coal lands for collecting this information. Archaeologists working north of the middle Yellowstone valley almost universally agree that currently available data indicate far less pronounced climatic fluctuations in post-Pleistocene times north of the Yellowstone than is indicated south of this region. The coal lands may be a transitional area between zones of major and minor climatic cycles. The evidence of movement of people in prehistoric times in and out of the transitional zone in response to climatic changes as well as the evidence of these multimillenia cycles may be buried in the soil above the coal beds.

Although it is outside the range of my experience, I am informed that the coal lands are also rich in fossils, not only of the early primates, but also of the great reptiles, including dinosaurs. Since there are relatively few places in the world where there are concentrations of dinosaur remains, it would seem tragic to destroy another resource with no effort to salvage at least the better specimens.

Elephants once roamed the Yellowstone Valley. It was on these mammoths and mestodons that the earliest known Americans feasted. Elephant remains always signal the possibility of the most exciting of all archaeological finds, North America's earliest man. There is a good possibility that such sites exist in the coal country.

It is evident that there are cultural and economic reasons for requiring a maximum utilization of the available resources and not merely the hydrocarbon resources, in the area to be strip mined.

For those who are interested, the Center For Indian Studies of Rocky Mountain College, Billings, Montana, has made copies of a document about the archaeology of the coal lands and the river basin salvage archaeological program. This document was prepared by the River Basin Surveys of the Smithsonian Institution. Copies are available here and on request from the Center For Indian Studies as long as the limited supply lasts.

It is proposed that a coordinated plan of salvage archaeology be instituted for the Montana-Wyoming-Dakota coal lands to prevent the irreparable loss of a valuable resource.

Salvage archaeology is underway in many places in the world today. Perhaps the greatest salvage archaeology effort to date was the detailed recording, and in some instances, removal, of the ancient Egyptian shrines along the Nile necessitated by the High Aswan Dam. Nearly every advanced country in the world contributed money and crews to that effort.

When it became obvious at the end of the second World War that many dams would be built in the United States for flood control and power generation, Congress inaugurated a program of river

basin salvage archaeology. Archaeological reconnaissance crews examined intended reservoir areas. Archaeological excavation crews followed when dam construction was authorized.

Many states now have archaeological crews that preceed highway construction, urban renewal projects and other land alteration activities.

Some pipeline companies have for years employed their own archaeologists to check the route of new pipelines, and financed the excavation of sites which the intended line would damage. Several utility companies in the United States and Canada employ or contract with archaeologists to perform salvage functions before new construction. One of the present coal operators does this in other areas, but apparently not in our locality.

Three possible approaches to coal lands salvage archaeology come to mind:

1. A federally administered program similar to the River Basin Surveys formerly operated by the Smithsonian Institution and recently taken over by the National Park Service: Under this system federally employed archaeologists would perform as much of the work as possible, with the balance being contracted by the government to universities.

2. A company operated program under standards approved by the federal government: Such an arrangement would involve the employment of an archaeologist and seasonal crews by the coal operator.

3. Contracts between the coal operators and universities for archaeological research: Such a system would require federal approval of archaeological standards as in the other cases.

Whichever approach might be adopted, the archaeologist in charge of the work would have the responsibility of promptly preparing a publishable report. Without publication there can be no dissemination of information or contribution to man's knowledge. The cost of publication must be considered in any salvage plan.

The degree of archaeological expertise needed in the coal lands is greater than in other situations because of the importance of the study of paleoclimates. Disciplines dealing with soil content would need to be involved in some phases of both the field work and the subsequent analysis.

It is my hope that any archaeological salvage program would apply to all land being stripped, whether owned or administered by a state, an individual, a corporation or the United States.

Such a program could be hastened by the state and federal lessors adding provisions to new leases that federally approved salvage arrangements are required. Bids on new leases might not be accepted from operators of other lands for which no archaeological salvage program had been approved, irrespective of land ownership of the other land.

While I find it quite distasteful to suggest the foregoing sanctions, I would not have made the suggestion if the need was not great and if the present operators had not neglected to take

action or refused to do so after the suggestion was made that salvage archaeology be instituted. The time for the exercise of company initiative in this matter unfortunately expired without voluntary action being taken. There are, of course, state and federal criminal penalties for the unauthorized destruction of archaeological sites on state and federal land.

There can be little doubt that existing coal operations are already beginning to cause the disappearance of archaeological sites. The need for salvage archaeology is immediate. The research facilities are available on the state university level and possibly on the federal level. If action is not taken at once it can never again be taken as to the sites now being chewed up. To delay at all would be an inexcusable waste of a natural and cultural resource.

A LEGISLATOR'S DILEMMA

E. W. Christensen

I wish at this time to add my personal congratulations to Governor Anderson and to the Montana delegation in the Congress of the United States, Senator Mansfield, Senator Metcalf, Congressman Olsen and Congressman Melcher for their part in conceiving and planning this most worthwhile coal symposium. I would also convey my thanks to Dr. Will Clark, and his staff for putting together this program and seeing that it moved smoothly. We are fortunate that the quality of people from both the public and private sector who have appeared on this program through the past two days are not only nationally known but in some instance internationally known. In the field of coal and coal development we have the cream of the crop appearing here with fresh new ideas and suggestions, hopefully this symposium will bear fruit in expanding the economic base of Montana, and personally I feel it will start in the very near future.

To me this date marks an anniversary for it was at this time of the year in 1964 that the first Montana coal symposium was held in Butte. Although Montana's coal development has not rung the cash register to the extent many of us would have liked there has been some encouraging progress along with disappointment. Montana's Coal Resources Research Council, moderately funded by the 1965 Legislature and formed by motion of the Board of Regents, has been functioning continually since its formation. On a limited budget it has been able to do several summers of field inventory work primarily on state owned lands that has firmed up data on our coal reserves. This data has been most encouraging since in almost all instances reserves have been confirmed in excess of those previously established and sometimes deposits of coal were found to be three times that of previously existing data.

The Council has cooperated in research at both Montana State University and University of Montana and at the School of Mineral Science at Butte. Since this panel addresses itself to environmental consideration perhaps the reclamation research supported by council funds along with private contributions of Western Energy, Peabody and Knife River Coal is pertinent. This is being carried on at Montana State University. The research effort dwells on such diverse items as ground cover and the relationship of cover to various slopes and exposures, creation of wild life habitat, erosion control, recreational sites, along with air and water pollution control.

Even such a brief five year resume of Montana's official effort to promote greater use of her coal has not been entirely favorable to the best interest of Montana's citizens. The coal leasing policies as they affect state owned land have twice run the cycle from negotiated leases to those requiring competitive bidding. Unfortunately Montana's prime state coal lands adjoining adequate water supplies leased for just over 23¢ per acre. This most inadequate return would make some join the camp of those who say "Let King coal, the sleeping giant, lie".

Representative E. W. Christensen, State Representative, District 8, Hardin, Montana.

It is perhaps fortunate that Montana's Coal Council has shown leadership in calling attention to our fabulous reserves since the State Planning Board, whose function should perform in areas such as these, in their biennial report to the 1965 session of the Montana Legislature did not even contain the word "coal". This is double hard to understand when this same report covered the Planning Board's program and plans for the biennium ending July 1, 1967. This might not be an important consideration to many of you but I wager it has been a shocking revelation to Mr. Perry Roys, who now heads our department of Planning and Economic Development. Enough of the past.

Certainly dilemmas are not unique to legislative decision, or for that matter to any decisions made by those in authority in the governing bodies at any level of the government. It is rare when a person in authority makes a decision in the Legislature or in her governing bodies where there are not very firm battle lines drawn on both sides of that issue. The battle lines seem particularly firmly drawn in the instance of Montana's potential coal development. What I think is unique in this situation is that the economic climate generated by the statutory requirements for reclamation enacted by the Montana Legislature will have a far reaching effect on the future of coal development in the State of Montana. Perhaps no single decision in retrospect will have the impact that those laws and their economic implications will have on either attracting or repelling coal development in Montana. The problem of bringing to Montana and it's citizens the required and needed services of government becomes evermore complex, its complexities are compounded because the tax base on which we levy the funds required to support Montana's government is not expanding at nearly the same rate as the needs of Montana government. I am not going to bore you with a great quantity of figures but I would only say that here in Montana the property tax base, real and personal, bears a tremendous share of the burden of taxation without our state. The property tax base is growing at approximately a 4 percent increase per year, not nearly enough to respond to the needs of Montana -- growing at least double this percent. It becomes increasingly obvious that when the base does not grow and the needs do grow that taxes must become more and more punitive. The growth of the Montana taxable income including both the personal and corporate tax base has been able to respond much better to the needs of Montana. I want to be certain that I am not confusing you with the words "taxable income" and "income tax", income tax, of course, is the money generated by any percentage of taxation you see fit to levy against any taxable income. This, of course, varies greatly with the rates of tax. But to look at the true growth, Montana's taxable income has grown at a rate during the past 10 years in the range from 8.5 percent increase each year to 10.8 percent increase each year. This is a reasonably healthy growth and has responded to the needs of Montana because of the growth. However, when we look at the standing of the State of Montana in regards to our per capita income we can readily see that this growth has not kept pace with the national trend. To those of you who might suggest another extremely fashionable method of taxation I would say only that taxes come out of pockets and when you take a greater percentage of the total income of the individual from his pocket the taxes become more punitive. We can all see that Montana needs an expanding tax base both in the property tax and income tax segments of our economy. There is no doubt in my mind that coal can be the leader in moving us forward in both of these areas.

Think in terms of a potential 350 million dollar investment in a complex of plants which perhaps will produce electricity through a coal-fired steam generating plant or by using the magneto hydrodynamic process of generation of electricity coupled with a petrochemical plant producing petroleum stock in immense quantities, and a refinery type processing plant for this petroleum stock, complemented by a plant which would produce methane gas.

This complex of industrial plants is referred to by the trade as a "COP", coal, oil and power consolidation. It seems particularly significant to me that in my home town of Hardin, the school district is undertaking a program referred to as "COP". In this instance the initials stand for Career Opportunities Program, and what better career opportunities program could be brought to Montana than an industrial giant of this type and the more than 1100 new jobs that would be required to staff it?

This seems almost an unbelievable figure, 350 million dollar tax base investment in the State of Montana, but I do not think it is unrealistic. Private and public capital could band together and form a corporation that would put together a complex of this type. When you couple that tremendous investment of capital dollars in the State of Montana with the employment that would be generated from it and the snowballing of the employment dollar, as it rolls down the street to the merchants, it is most impressive. The far reaching effects of such investment here in Montana are almost beyond comprehension, is it any wonder that this is attractive to those charged with balancing Montana's budget. In spite of this attraction Montanans who are charged with the decision making policies of this state must, of course, be ever cognizant of the clean air, clean water concept. It can take second place not at all. It is a prime consideration. It seems fortunate whenever I need a refresher course in the "clean air, clean water" concept my schedule sends me on a reinforcing trip. Probably the most revolting sight to me in the recent past was my first view of the polluted Potomac River. Only a couple of weeks ago while visiting the United States Military Academy at West Point I viewed at close hand the Hudson in much the same disgusting condition. The necessary air trip to visit these places give vivid testimony to the increasing problems of industrial haze.

Also the reclamation of strip mine areas and their return to beneficial use must be fully considered. I believe it is in this area, the reclamation of strip mine lands, that there is room for compromise. The 1967 session of the Legislature saw fit to pass enabling legislation to implement a voluntary agreement system in which a specified division of Montana government would enter into an agreement with industry as to what would be the proper return of strip mined areas to beneficial use. The same Montana agency that had the authority to enter into this agreement also had the authority to approve the procedures and the dollars spent in relaiming the land and in essence approve a tax rebate to the coal producing companies. In other words, the strip mining tax is five cents per ton and approved reclamation costs could reduce the tax of the company involved. The voluntary agreement has been signed with three of the leading coal producers of Montana. In fact I think figures will indicate that they are perhaps producing and using within our state and shipping without our state 99 percent or more of the coal of the Montana coal being stripped at the present time.

The 1969 session of the Legislature enacted a mandatory permit system if no voluntary agreement is in force requiring the coal producer to comply with the act and perform certain reclamation type functions in regard to the spoil banks and return of the land involved to beneficial use.

Certainly the citizens of Montana are entitled to the protection that is afforded by a mandatory reclamation requirement. However, we also must realize that there are many different and unique situations in the areas where coal mining is taking place and perhaps will take place in the future. Each situation must be responded to by a considerable latitude in the type of reclamation that should take place. I realize that it is extremely fashionable to point out throughout the United States and here in Montana in the Colstrip area the scars that are upon the land. We do not want these scars on our land and we are sorry they are there, but I think there has been a great change -- improvement, if you will -- in the attitude of industry towards reclamation.

Undoubtedly in any of our businesses, and this is true of my small business at home, yours, and the major businesses of the United States, the most priceless commodity on the balance sheet is goodwill. It is impossible for a company to maintain the goodwill of the citizens of the state in which it is operating if they do not perform reasonable reclamation procedures after the strip mining takes place.

I have great confidence that those in authority in industry and those in authority given them by the Legislature of Montana can sit down and work out in every instance the type of reclamation that is most suited to the area involved. It is virtually impossible, in my opinion, to legislate completely the guidelines which must be followed for the reclaiming of the strip mining areas. You must have confidence in people having the ability to look a situation over, arrive at a mutual conclusion as what is the most beneficial use of the area affected and then to proceed on that basis.

Montana has some advantage in that her environment has not yet been damaged to the extent of that of a great number of areas. Experience show us that after air and water and land have been damaged it is almost impossible to reverse the process at any cost. We then must focus our attention on correcting the problem in Montana where it now exists and holding the line firmly where we still have control. Industry must recognize the protection of environment as a cost of production. It is unfortunate that this becomes a consumer pass-along cost but in reality all costs find this resting place anyway. The thought that a nation that can put a man on the moon has the technology to keep his environment from being blighted is certainly not original with me but seems very apt. It is interesting to note that magneto-hydro-dynamic generation of electricty will greatly improve the control of pollution and one of the chief reasons it can now be given practical consideration is because of the aerospace experiments with the high temperature gases in solving the ballistic missile re-entry problem.

It is my opinion that it is possible for the state of Montana to benefit greatly by the economic effect of coal development in any and all of the many potentials coal utilization has, and still protect our priceless environment.

SEIZING THE OPPORTUNITY FOR REGIONAL ENVIRONMENTAL PLANNING

George Darrow

I want to thank the sponsors of the Montana Coal Symposium for this opportunity to comment on the environmental aspects of eastern Montana's impending coal development. The sponsors of this Symposium have demonstrated their foresight in recognizing the need to anticipate the environmental consequences of massive regional industrialization.

Such foresight has not been common in the past. The crisis of the environment, which we confront in our country today, is the result of the unplanned, unforseen consequences of man-induced change. Today we have an unparalleled opportunity to initiate planning which will allow this development to be based on ecological principles and knowledge. An ecological accounting, which evaluates the environmental cost of alternative plans for development, must take its place alongside the conventional analysis of economic alternatives.

As a geologist who has been actively engaged for the past 20 years in developing Montana's resources, I find it an exciting prospect that Montana's coal industry is now nearing the day when it will join Montana's oil and metal mining industries as a major pillar of our economy. As the author and principal sponsor of the Montana Water Resources Act of 1967, which initiated the preparation of a State Water Plan, I have a continuing interest in comprehensive planning for the beneficial use of this vital natural resource. Water is the 'companion resource', without which no other resource development or us is possible. As a member of Montana's Comprehensive Health Planning Advisory Council, and Chairman of the Council's Sub-Committee on Environmental Health, I have been deeply involved with another category of natural resources, the environmental resources of clean air, pure water, fertile soil, and natural open space upon which the quality of human life is so dependent.

Others have spoken of the need to preserve environmental quality in a region now facing the prospect of an unprecedented, massive industrialization. There should be no further need to emphasize that the unimpaired health of the ecological systems in this region comprises an environmental resource with important social and economic benefits. Over the long term, environmental values become economic values necessary to the sustained productivity of any region.

The example of an impoverished Appalachia vividly illustrates the consequences of resource development in an earlier era which failed to consider its impact on the total environment. It is unthinkable that this dismal episode of history could be allowed to repeat itself in eastern Montana.

Surely, with the advanced technology that is now available to

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us, with foreknowledge of the effects of environmental blight in other areas to enlighten us, and with a rapidly growing ecological understanding of the vital processes of natural systems, we can plan for both increased productivity and sustained livability within this region.

Seldom in this nation's history has there been an opportunity such as we now have to anticipate, and knowledgably plan the economic development of an entire region before irreversible resource decisions have mortgaged its future. In this circumstance, I believe that we can aim far higher than mere efforts to minimize damage to the environment and reclaim waste lands. I believe it possible to make constructive, creative use of this opportunity in shaping a better environment throughout eastern Montana. This magnificent expanse of prairies and hills and rivers can become a place where the amenities of our civilization and the amenities of nature co-exist in harmony. My remaining remarks will be directed toward outling the planning effort that will be required to achieve this goal.

There is growing evidence that the Yellowstone Basin of eastern Montana is destined to become one of this nation's prime energy sources. The firm documentation of coal reserves in place, combined with the proximity of adequate water supplies, the emerging trends of technology and the developing economic demand for energy, all support this conclusion.

Energy which was originally captured by green plants from the incoming solar energy of an earlier geologic period will be released from its fossil bed and converted into both electric energy and synthetic hydrocarbon fuels. Other derivative chemical substances can be important by-products. A full conversion in place of this versatile natural resource -- coal -- can provide the solid foundation for a diversified economic complex in eastern Montana.

A surprising historical precedent exists for an economy based on the full utilization of a single natural resource. Roughly a hundred years ago, the residents of eastern Montana based their economy on the complete utilization of one basic resource -- the buffalo. By the ingenious exploitation of the buffalo, the Indians and trappers enjoyed a primitive version of the affluent society. They ate the meat, liver, brains, and other miscellaneous parts and drank the blood. The uneaten meat was dried and then pounded into a fine powder. After adding tallow and marrow fat, and mixing in berries and sometimes grasshoppers, they ended up with a concentrated high energy food called pemmican which was stuffed into clean sections of the large intestine.

They passed the winter snugly inside their buffalo skin lodges, lying on soft piles of buffalo robes, warmed by a buffalo chip fire, munching on their pemmican. For diversion, they made spoons, cups, and bows from buffalo horns. The bows were strung with buffalo sinew bowstrings. This pleasant life lasted until an insatiable export market developed back East for the hides and tongues, and that was the end of the buffalo economy.

Now, getting back to 1969 and looking ahead into the final third of the 20th century, how can we develop a coal based, diversified economic complex in the Yellowstone Basin, with the necessary environmental safeguards, which will bring the greatest bene-

fits to Montana. First, I would assume that this state would seek to obtain the fullest possible conversion and utilization of the coal resource in place. This type of development would provide the largest number of diversified employment opportunities.

A 100,000 barrel-per-day hydrogenation plant, for example, would have some 2,500 to 3,000 highly skilled employees on its payroll. With dependents, and the other people needed to provide community services and supplies, just one such plant would require a new town with a population of perhaps 15,000 people. This town would be larger than any existing Montana city east of Billings. With the anticipated installation of both electric generating plants and hydrogenation plants to produce hydrocarbon fuels, an industrial complex could develop over a period of years which would support say 350,000 people, or a 50% increase in Montana's present population.

The economic, social, and environmental impact of industrialization on this scale poses awesome problems. It requires nothing less than comprehensive, regional, environmental planning to anticipate the problems. We must seize the opportunity to employ the same planning tools in shaping a humane environment for man in an undiminished natural environment. To this end, I will briefly outline five proposals and recommendations.

ONE. I would recommend a complete ecological inventory of each proposed mining site, industrial site, or town site prior to development. This inventory would provide base data before any disruption of ecological systems had occurred. Data should be gathered on soils, water resources, surface geology, vegetation, wildlife, and topographic features. The interacting natural systems and interdependent ecological communities which extend beyond the strict limits of the site should be delineated. Prime agricultural lands, flood plains and aquifer recharge areas should be given special consideration.

TWO. Each ecological inventory should be evaluated by a team of diverse specialists with a working knowledge of ecological principles. Development options with least environmental cost should be formulated. Opportunities for environmental enhancement should be explored. A program for subsequent rehabilitation of mined lands should be initiated in progressive stages.

THREE. A regional ecological inventory or, if you will, a systems analysis of the regional resource interrelationships should be prepared. I am not talking about a mere summation of the aggregate substances and 'things' of nature. I am instead talking about an ecological study of the unseen interacting processes and the subtle interdependent relationships which exist within the natural resource systems of eastern Montana. After the base data has been assembled, the consequences of induced changes should be evaluated by interdisciplinary teams. Every proposed change creates secondary changes which reverberate throughout all of the interacting, interdependent systems of the environment. With adequate planning, the adverse side effects could be avoided and beneficial changes could be promoted.

FOUR. The human environment, of course, also includes <u>all</u> of the man-made social, economic, and cultural systems. Among these systems and sub-systems are, (1) an industrial system, (2) an

agricultural system, (3) a residential system of cities, towns and neighborhoods, (4) a commercial system, (5) an educational system, (6) a park and recreational system, (7) a system of cultural amenities, (8) a communication system, (9) a transportation system, and finally, but certainly not least, (10) a political system. All of these systems will be drastically altered by the massive impact of the regional industrialization expected in the foreseeable future.

The same ecological study of the interplay among these systems should be made, the consequences of impending changes evaluated and the best planning options selected. The goal should be to preserve significant social values, including social values of the environment, and to further the attainment of meaningful human purpose.

FIVE. Montana's capabilities to undertake this comprehensive regional planning effort are limited. I therefore propose that a mission oriented, regional planning organization be formed to undertake this task. The participants in this organization should include both Montana's state government and its university system, agencies of the federal government and the industrial organizations with an active role in the regional development. Such research competence and outside expertise as is required for this innovative planning effort should be sought out and engaged wherever in the country it is available.

In view of the deep concern for Montana's environment which has been expressed by our Governor and the entire Congressional delegation, I am confident that the efforts necessary to create and fund this planning mission can be carried to a successful conclusion.

A basic premise of the whole planning effort must be the undeviating recognition that successful planning is only done <u>with</u> people, not <u>for</u> people.

In conclusion, I want to emphasize that piecemeat project engineering, fragmented social programs and narrowly conceived planning goals are totally inadequate for the environmental challenge we now confront. After all, it is the application of sound engineering practice and least economic cost that have brought us to the brink of today's environmental crisis. Planning for the future demands an ecological attitude. Montana cannot fail its responsibility to future generations. And in a larger perspective, surely the future of a large portion of the Missouri River Basin is a matter of national importance. May our human vision be appropriate to the dimensions of the Big Sky Country!

REMARKS ON ENVIRONMENTAL PLANNING

Theodore J. Wirth

From Apollo space flights, earth appeared as a grand oasis in the vastness of space, a fragile outpost of life in a lifeless universe. On closer inspection from space, there began to appear cancerous scars as blemishes on the skin of a beautiful woman. All signs of how men have plundered the planet we call Earth!

I moved to Montana nine years ago because to me, she was like an oasis in a country fast being defiled by man's ingenuity. I saw in Montana and the northern Rocky Mountains a beautiful woman with unblemished skin. I saw a land as yet unravaged, where man had not yet gone on a spree and wasted.

Perhaps because I am a bit more sensitive, but also because I live in Montana by choice and not by chance, I view this great, wide, wonderful State of Montana with a little more critical eye than the native. The mountains are still there, rising serene and snow-clad from their forested foothills. Cattle still graze on the vast, golden stretches of rangeland. Streams still tumble out of canyons and wind across valleys to join the great rivers.

I can still travel over miles and miles of highway, experiencing anew the grandeur and diversity of Montana's natural endowments. Hearts and minds can still be lifted as we see the wonders of our heritage, as we feel the power and beauty of this land. This feeling can overwhelm us in every section of the state, whether we drive across the highline, through the Swan Valley, up the Madison, or down the Yellowstone.

Taking a closer look at this superb expanse of land, this big, beautiful bundle of sky cracking mountains, bellowing plains, and surging rivers, I see the beginning of signs of abuse.

Oh, at first glance there seems to be nothing seriously wrong. However, each time I travel or fly across the state I can see some new blemish; a new signboard that blocks my once favorite view of the Crazies; the ugly gash of a new interstate on what used to be a pine-covered bluff; the tangle of streambed debris, all that is left of a shining river that used to flow free. More frequently my senses are assaulted by the proliferation of transmission lines, dozer tracks, old car bodies, abandoned structures, highway borrow pits, and gravel piles.

Perhaps insensitive people <u>can</u> dismiss all these visual blights that are spreading over our state. And many of us, perhaps, are able to discount this or that particular scar or blemish as inevitable or unimportant. But enough minor scars and blemishes to our naturally beautiful Montana landscape can evolve into a major disease -- the scars can cut off circulation; the blemishes can fester and become a cancer that slowly encompasses and consumes the once beautiful body.

I have always contended that Montana's natural beauty and

Theodore J. Wirth, Land Planning Consultant, Wirth and Associates, Billings, Montana.

environment is one of her last, if not her greatest, natural resources. This great natural resource I call our environment which attracts tourists and new citizens is enduring and subject to appreciation in value if we show concern and plan to conserve and use it wisely.

The dauntless pioneer -- who tamed the west -- this Renaissance man of many skills who could survive in a deserted prairie with only the simpliest tools and possessions -- this pioneer has disappeared from the scene, and the rugged individualist's attitude toward private property should disappear with him.

A generation ago we were plummeted into a depression, and we climbed out of that into a World War. The whole productive energy of our society was concentrated overwhelmingly towards problems affecting the basic fabric of society -- survival! Since the end of the war we have been very busy putting bigger feathers in our nests. We have paid little attention to the chaos of the environment. There is today, however, a new mood in the American people. A new sense of individual responsibility.

All of a sudden people seem to be noticing what is actually there in their outdoor environment -- and to realize that it is their responsibility. A group of citizens even took the Federal Power Commission to court, because they said they did not pay enough attention to scenery, or the fish in the river, and, of all things, they won their point.

I believe we are now about to embark upon an era of quality in the environment. Perhaps this could be the theme of the 70s. A sense, an understanding, that we are a society, a civilized wealthy society which does not have to live in its own debris any longer. Since this symposium is concerning itself with a resource -- coal -- and an industry -- mining -- I think it would be well to take heed of the public concern for our environment which I have mentioned. There is another industry that has taken heed, but also taken constructive action. I am referring to the electrical utility industry!

The industry, on its own volition, undertook to publish a report to the Citizens Advisory Committee on Recreation and Natural Beauty. It was a study by the Electric Utility Industry Task Force on Environment, entitled "The Electric Utility Industry and the Environment."

Even more important perhaps than the recommendations of the report and how they will affect and improve our daily lives and environment, is the fact that it is a self-analysis by the industry itself. It is a self-analysis and program of action that should be an example to all of industry. If the mining industry, the lumber industry, and others would be as honest and soul-searching, as the electric utility industry was in this report we could look forward to better environment and recreation opportunities for generations to come.

I am the 3rd generation of planners in my family and never have we seen such a great stride in the right direction as represented by the Utility Industry Report. At last we have something besides just a lot of words -- and by the industry itself! As consultants to no less than nine utility companies we can attest that the honest concern for environment reflected in the report

is in actuality being exhibited by deeds.

When President Nixon spoke on conservation in the 70s, he said, "We need a strategy of quality for the 70s to match the strategy of quantity of the past. Modern technology and old-fashioned pride in America can and must combine to win the battle for our environment. The technological know-how which helped to place man on the moon can be used to help him keep areas of clean rivers and streams, and pure air on earth."

These problems, which we have made for ourselves, must be solved, and the only way we are going to solve them is by establishing unprecedented coordination and effort between industry, government, and people. Further, we must stop compounding problems with words, stop depending on legislation, and start trying to solve the problems by understanding what they are; what really caused them; and what can be done about them; and not who to blame! Industry has been known to be short on words and very long on the necessary mechanics and know-how to spend money productively. It is well then, that the mining utility industry assume the position of a leader in taking positive action and specific steps in solving some of the environmental and visual pollution problems of their strip mining operations.

Can we serve the demand for the product, in this case coal, and at the same time provide for environmental quality. We must!

It will not happen, however, if the conservationist has a closed mind, or if the industry ignores the environment. It will only happen if both open-mindedly sit down, understand each others objectives and problems, and work out a solution. This working out of a solution must employ imagination and a willingness to experiment in order to make the maximum use of what we do have. If we do not, we might have forced upon us by the politician a yoke that would stymie the very foundation of our existence.

If only the rugged individualism that settled the West could be channeled into effective and creative thinking we could preserve the environment. As I pointed out, there are instances where this individualistic pioneer attitude has been put to work, and where the utility companies have put their money where their mouth is. The cost, as well as the responsibility, of preserving environment must be accepted as a part of the basic cost of doing business.

In conclusion, I would like to re-emphasize that both industry and government, working together must not only restore our polluted air and water and our defiled land, but must take steps and make plans to assure that this environment of ours will continue to be one of our greatest natural resources after the other resources are depleted!

Abstract of Luncheon Address

MONTANA'S COAL RESOURCE POTENTIAL

Congressman John Melcher

Eastern Montana can have both cows and coal provided lands mined for the huge energy potentials they contain are left so grass will grow again, Congressman John Melcher told the Montana Coal Symposium here today.

"Part of the cost of coal mining is reclamation of the land so that cows, sheep and deer still have a home," he said. "Experience indicates that it will be surprisingly inexpensive."

Melcher stressed the great potential for use of Eastern Montana coal for manufacture of electricity, synthetic natural gas and synthetic petroleum.

He insisted that the development must be planned so as not to damage the environment.

"It means that our streams and lakes should be of the highest possible quality -- free of the thermal pollution that often does irreparable damage to the balance of life, free of the poisonous chemicals and other pollutants that kill life in the water outright, and free of polluting garbage or sewage.

"It means, finally, that we can develop our coal reserves and at the same time keep our prairie skies clear and clean, keep our livestock and wildlife alive and healthy and preserve Montana's unique natural heritage."

Moving energy industies out into Western states such as Montana has great potential because there is so much pollution of air and water in congested urban areas, Melcher said.

This is one aspect of a "terrible imbalance" which has seen rural areas lose population and urban areas become more and more overgrown, according to the Eastern Montana Congressman.

"Rural and urban problems feed each other. As the opportunity to have a decent living declines in the rural areas, people flock to the urban areas. It is a vicious circle which must be broken if this Nation is to continue being the greatest on earth."

The Pacific Northwest, a rapidly growing and increasingly urbanized area, Melcher said, has a plan for a network of nuclear plants near population centers, but nuclear costs are increasing rapidly and environmental problems are still unsolved which may make energy from Montana coal a more desirable energy source for the area.

He cited the failure of the Johnson and Nixon Administrations and of Congress to work for a balanced energy policy, saying that the budget for nuclear power plants this year is over $164,000,000,

Congressman John Melcher, (Forsyth, Montana) House Office Building, Washington, D.C.

yet the Administration would not ask for, nor Congress appropriate, $1.7 million to begin a magnetohydrodynamics (MHD) pilot plant program in Eastern Montana this year.

"MHD is a most promising new technique, which has been recommended by the highest scientific authorities, for generating power from coal or other fossil fuels, without air and water pollution and with great improvements in efficiency," Melcher said.

PANEL: EMERGING TECHNOLOGY

Remarks of the Panel Moderator, R. O. Marritz

As we come to this final panel of an extremely exciting and thorough program, we consider the energy resources of the Montana coal in the context of new and emerging technology.

In a sense, we may view this panel as a commencement ceremony, as we peer into the uncharted waters of new, sophisticated methods of energy conversion and processes for converting a relatively dirty solid fuel -- subbituminous coal -- into purer synthetic liquid and gaseous fuels. You have already heard more than ample data relating to the size of the resources that lie just beneath the earth in Montana and its sister states. The amount is so large that it seems to be -- though it really is not -- inexhaustable. The conversion processes we are going to be discussing have a good deal to do with the conservation, and wisest and best use of this resource, which has been discussed here also.

MHD, and gasification and liquefaction of coal are not yet commercially operable processes. But no one doubts that they are technically feasible or that, in all likelihood, they will soon attain some degree of commercial applicability. How quickly the needed research and development and proving out work can be completed for these processes depends ultimately on external market forces that I would not hazard to anticipate. I am only certain that they will be developed.

About gasification and liquefaction, I know very little. About MHD -- which stands, of course, for magnetohydrodynamics -- I know only a little more, but I am forced to recall Will Rogers' observation that, "Nothing that you cannot pronounce will ever work."

In MHD, which I can pronounce, we have a conversion process which promises efficiencies of about 60 per cent (bettering present conversion ratios by 50 per cent), little water pollution and negligible air pollution, along with low capital costs. In these days of rising costs and increasing concern for the environment, this is nothing to take lightly.

And, as we begin to talk about impending shortages of natural gas and liquid fuels -- whether these shortages have actually been demonstrated or not -- I know that we are going to have to consider the hydrogenation processes for coal we will be hearing about today, as well.

Now to our panel.

Robert O. Marritz, Executive Director & Staff Counsel, Missouri Basin Systems Group, Denver, Colorado.

MAGNETOHYDRODYNAMICS POWER GENERATION

R. J. Rosa and W. D. Jackson

The concept of an electrical generator in which the armature is an electrically conducting fluid has its origins in the studies by Michael Faraday, the 19th Century British experimentalist who laid the foundations for the development of electrical machinery. In the subsequent development of this machinery, solid conductors were favored although magnetohydrodynamic machines were the subject of patent applications from 1910 onwards. This initial phase of MHD development culminated in the early 1940's with the construction of a relatively large and sophisticated MHD generator using a gaseous working fluid.[1] The experiment with this generator failed because the properties of ionized gases were not sufficiently understood at that time. Success in this regard occurred in the early 1950's and laid the foundation for the intensive development of MHD generators which has occurred over the past ten years.

The interest in MHD power generation stems from its inherent simplicity. It is a heat engine which combines the function of both a conventional turbine and an electrical generator for direct conversion of heat into electricity. Figure 1 shows the principle of the MHD generator and compares it with the steam turbo-alternator. The only requirement for the MHD generator is that the temperature of the gaseous working fluid be in a range where the gas has an adequate electrical conductivity.

In this paper, discussion centers on the types of MHD generators suitable for operation on an open-cycle system. In this case, the working fluid is a gas derived from combustion of a fuel in the temperature range between 4000 and 5000°F. Thus the highest operating temperatures are found in the working substance itself. The MHD generator can handle gas conditions which would quickly destroy a conventional turbine, because the MHD generator has no highly stressed, close tolerance, moving parts. The solid materials from whcih the generator channel walls are constructed are readily accessible for cooling and MHD generators are accordingly attractive for high temperature applications where turbine operation is prohibited.

An important feature which distinguishes MHD generators from other heat engines is that the basic conversion is a volume process while losses are proportional to surface area. These generators become more attractive as their size increases. It has been pointed out[2] that an MHD generator combined with a rocket combustion chamber such as a Rocketdyne F-1, 1.5 million pound thrust rocket engine could yield 10^4 MW.

The MHD generator also shares with rocket engine technology the ability to start and reach full power very rapidly. This characteristic makes it possible to deliver power at several hundred of megawatts or more in a few seconds. It is for this type

Richard J. Rosa, Avco Everett Research Laboratory, Everett, Massachusetts; and
Dr. William D. Jackson, Avco Everett Research Laboratory, Everett, Massachusetts.

of application that the MHD generator has already achieved its first pilot operation.[3]

During the past ten years, intensive efforts have been made in the development of MHD generators and very substantial progress has been achieved. These efforts have been international in character[4] and the major emphasis has been placed on the development of MHD generators for commercial electrical power production. Other applications, such as the provision of electrical power in space vehicles, have also received attention and here special systems have been devised, including those which are compatible with a high-temperature nuclear neat source. For commercial power production, however, the development of a suitable nuclear reactor presents formidable problems. In the absence of radical developments in the nuclear field, it is combustion-driven MHD generators which offer the potential for substantial improvements in commercial power generation.

The ability of MHD generators to operate at high temperatures gives them a clear thermodynamic advantage with regard to increasing efficiency of conversion of heat into electricity and they promise to achieve very substantial gains in this direction. While emphasis was placed on central station plants for base-load operation in the early stages of the current development of MHD generators[5], the need for emergency and peaking generators also offers a potential application for MHD[6]. In addition to the performance gains which arise from the basic characteristics of MHD generators, favorable system economics can be shown to result from their use and they offer important advantages with regard to pollution control.

SYSTEM ARRANGEMENTS

Open-cycle systems are usually of the regenerative Brayton type and may have an associated steam plant as shown in Fig. 2a. In this example, coal serves as the fuel and it is fed with preheated air and seed material to a burner in which temperatures of around 4600°F are achieved. After passing through the generator channel, the combustion gases are used to preheat the incoming air and to drive the boiler of the supplementary steam generator. Removal of the seed material is necessary for both economic and environmental reasons. This clean-up stage also enables particulatelate matter to be removed from the exhaust gases. As will be discussed later in the paper, the conditions of operation of the MHD generator are favorable for a further clean-up stage in which both sulphur dioxide and oxides of nitrogen are removed. The system is completed by an air compressor and an inverter network; the latter converts the intrinsic DC output of an MHD generator to AC line frequency whenever this type of output is required.

Many variations on this cycle are possible and one important example is shown in Fig. 2b. The basic layout is similar to the arrangement just described except that the steam cycle is replaced by an air turbine. Both cycles are shown to attain the necessary combustion conditions using compressed, preheated air. However, oxygen enrichment can be employed and all but a simple gas cleaning system can be eliminated downstream of the MHD generator as indicated in Fig. 2c when a simple, low-capital cost unit is required. The generator channel itself is almost invariably considered to be of linear geometry and the flow, either subsonic or supersonic,

is steady. As is now well established,[7] the current density and electric field directions do not coincide in the magnetic field region of the channel. To cope with this Hall effect and its attendant axial and transverse components of the electric field, the boundary conditions must be carefully selected and several alternatives are possible.

GENERATOR CONFIGURATIONS

Various channel configurations are illustrated in Fig. 3 and usually involve some form of electrode segmentation to prevent direct short circuiting of the axial or Hall field. The most obvious arrangement is to segment the electrodes to allow the build-up of the axial field and to accept the electrical output from the large number of terminal pairs thus formed. While such an arrangement provides no particular difficulties when the electrical output is obtained through solid state inversion equipment, this segmented Faraday generator clearly cannot provide two-terminal DC output.

A two-terminal arrangement and a simpler construction technique can be obtained by taking the electrical output via the Hall potential. By short circuiting the Faraday terminals, this output can be obtained axially by connecting to the first and last electrode (as a practical matter, to control current density, several electrodes are used). Short circuiting of the Faraday terminals can be achieved by fabricating each electrode segment from a continuous ring or loop.

A third possibility is to select the electrode short circuits in such a manner that they coincide with the equipotentials in the generator. This "diagonal" generator retains the basic features of the Hall machine with the advantage that it is not Hall parameter dependent, but this is only the case for constant operating conditions. If these are changed (e.g. through load fluctuations, the generator performance deteriorates.

GENERATOR PERFORMANCE

Very substantial progress has been made in improving both the performance and life time of open-cycle generators during the past few years. In the United States, the LORHO generator (Figure 4) which has an installed thermal capacity of 430 megawatts, has delivered an electrical output of 18 megawatts for a 3-minute run. The Avco MARK V generator, shown in Figure 5, has achieved a gross output of 32 megawatts. Continuous operating times substantially in excess of 50 hours have been reported for the U-02 installation[8] in the Soviet Union (Figure 6), for the long-duration test facility constructed by Toshiba near Tokyo, Japan, and in the Avco long-duration test facility (Figure 7). The linear dimensions of the biggest generators operating or under construction are in the order of several meters and thus it is possible to obtain high electrical power outputs combined with high power densities (maximum of 30 megawatts/mater^3). At the same time the strength of the magnetic fields has steadily increased and 3.3 Tesla was obtained under self-excited conditions in the MARK V generator.

A number of different approaches have been taken in the study

of open-cycle generators. On the one hand, several small-scale installations which include many of the components required for the complete MHD system have been developed, the most complete example of these being the U-02 installation in Moscow. This has delivered a maximum of 43 kilowatts and is of particular interest in that the power was delivered through a solid-state invertor system to the Moscow grid. In other installations, the facility consists only of a combustor, nuzzle, generator duct and magnet, and the emphasis is on generator studies rather than long-duration operation. This is so for the Avco MARK V machine and also for the Japanese Mark 2 generator at the Electrotechnical Laboratory in Tokyo.[9] The Krzhizhanovsky Institute of Power Engineering in Moscow has constructed a facility of this type known as the ENIN-2 which has an input thermal power of 250 megawatts and run times up to 15 minutes.[10]

In the matter of channel configuration, all types have been tried. The LORHO is a Hall machine with a circular cross section whereas diagonal configurations are favored in the ENIN-2. The segmented Faraday design has frequently been adopted as in the Avco MARK V generator (Figure 8) which employed a peg wall construction for the insulator wall surfaces.

The construction of high-field strength superconducting magnets has been shown to be practical and this type of magnet will be used with future MHD generators. Figure 9 shows this Avco model superconducting magnet which achieved a field of 4 Tesla in a 12 inch daimeter, 5-foot long bore.[11]

AUXILIARY EQUIPMENT

The successful operation of a complete MHD power plant depends heavily on the development of auxiliary equipment including combustion chambers, heat exchangers, seeding techniques and seed recovery systems. Seed injection may be accomplished either in dry powder or dissolved form. Both methods are now employed in generators currently under operation and the behavior of potassium salts in the presence of sulphur and vanadium has been extensively studies[12] with encouraging results.

Electrostatic precipitators, bag filters and cyclone separators are all under consideration as methods for effecting seed recovery, and collection efficiencies in excess of 99% have been obtained. The seed material is collected as potassium sulphate and particle sizes are typically of the order of a few microns in diameter. In this case, the cyclone separator is not particularly well suited for seed recovery purposes. This is confirmed by one experimental study in which efficiencies of only 10% were obtained for this type of separator.[13]

Realization of the predicted performance of an MHD cycle very critically depends on development of a successful high-temperature air heater. Good progress has been made in this direction. Generally, the air preheaters considered have been of the regenerative storage type with either fixed or moving beds. Emphasis has been placed on the development of a directly fired heat exchanger; the separately fired unit, although it avoids problems of seed and ash corrosion, involves a considerable thermodynamic penalty.

A typical preheater employing a fixed bed construction is

shown in Figure 10. In this case, the bed is fabricated from high-purity magnesia and preheat temperatures of up to 2000°F have been attained under conditions simulating the seed and ash content of typical coal combustion gases. With a clean gas, this temperature[14] was raised to 3000°F. The air preheater for the U-02 installation employs a pebble bed and includes two units which are switched by water-cooled gate valves to extend operations; the air temperature at the combustion chamber inlet varied by less than ± 10°F as the units were cycled.

The requirements for an MHD conbustion chamber are that combustion should take place at high temperature under pressure and in the prescence of alkali seed material. A number of tests have now been successfully completed using coal, oil and gas; e.g. the conbustion chamber of the U-02 facility was operated with natural gas and lined with zirconium oxide.[15] This combustion chamber has thus far operated successfully for over 1000 hours. It was shown that zirconium oxide is suitable for high-temperature linings in the gas-fired case for temperatures up to about 4100°F.

REFRACTORY MATERIALS

Refractory materials in MHD systems have been intensively studied and zirconia has received a large share of this attention. In the MHD channel this material can be used either as insulator or electrode material, depending upon the temperature range and the additives employed. As a conducting material, best results are obtained at temperatures between 2200 and 4000°F and, as it undergoes structural changes at approximately 2200°F, it must be combined with a stabilizer such as titanium oxide or yttrium oxide. In addition, its low thermal conductivity makes it necessary to use very thin layers of zirconia supported by a metal backing to permit the required heat fluxes.

The erosion and corrosion of zirconia from surfaces may be overcome by the injection of powdered zirconia into the combustion plasma, together with the alkali metal seed, under conditions such that a saturated zirconia vapor is attained. By careful control of surface temperatures, loss of zirconia can be made up by deposits due to the condensation of this vapor. Figure 11 shows the interior of a small Avco channel which was operated for 200 hours using this technique. The voltage developed by each electrode module, with respect to the entrance electrode, was compared at the beginning and the end of this run and showed negligible deviations over the entire period.

CYCLE STUDIES, ECONOMICS AND ENVIRONMENTAL CONSIDERATIONS

The projected efficiencies of large dual-cycle systems are initially in the range of 47 to 50% and improvements in technology could later increase this to 60%. Estimates of the cost of generating electricity in coal-fired MHD power plants are presented in Figure 12 which illustrates the variation in the cost of generating electricity as a function of the fuel cost for different coal-fired power plants, MHD and conventional. For comparison, the estimated electric energy cost from present nuclear plants is plotted as a constant.

The high-temperature MHD energy conversion process, with its

higher attainable conversion efficiencies, provides opportunities for the reduction and control of environmental pollution from power plants. In the case of atmospheric pollution, high-temperature combustion and subsequent rapid expansion and cooling of the gas in the generator results in gas chemistry that favors the economic removal of oxides of nitrogen and sulfur, the major pollutants produced by the combustion of fossil fuel.

Fixed nitrogen can be produced in the effluent gas by burning with a stoichiometric mixture or with a slight amoung of excess air. Under such conditions, the rapid expansion and subequent cooling of the gas in the MHD generator fix the nitric oxide in the gas. This renders the economic recovery of fixed nitrogen very attractive, particularly as the NO equilibrium concentration may be as high as 1 to 1.5%. The recovery of fixed nitrogen can be combined with removal of sulfur from the gas by utilizing the oxides of nitrogen to convert SO_2 in the gas to SO_3 which can be readily removed. Initial experiments conducted to determine the feasibility of utilizing nitrogen oxides in MHD combustion gases for the removal of sulfur have demonstrated that the SO_2 concentration in stack gas can be reduced to as low as 100 ppm when burning fossil fuel of high sulfur content. The conversion of SO_2 to SO_3 by nitrogen oxides has been utilized in the industrial production of sulfuric acid by the lead chamber process.[16]

All power plants must reject heat and the amount of heat rejected drops rapidly with increasing plant efficiency. This is so because the fraction of the heat energy supplied with the fuel and converted into electricity is the efficiency, , whereas the fraction of the fuel heat energy rejected to the environment equals that not converted to electricity, or (1 -). Thus the total amount of heat rejected per unit of electricity produced, Q, is proportional to (1 -) divided by the efficiency, , or Q = (1 -)/ . The rapid decrease in heat rejection with increasing cycle efficiency is illustrated in Figure 13. The heat rejection from different thermal power plants to the condenser and otherwise is indicated in the figure for comparison.

Base load MHD power generation will at first probably be combined with supplemental steam power generation. Because of their higher efficiencies, MHD steam-power plants would need about half the amount of cooling water necessary to operate conventional fossil fueled steam power plants. Compared with present nuclear power plants which are the least efficient, the amount of cooling water necessary would be reduced to about one-fourth. In addition, the nature of the MHD process, as shown earlier in Figure 2b, is such that cycles are possible without the necessity of providing cooling water for steam condensation.

CONCLUSIONS

The successful operation of large experimental generators and the extensive testing of materials for both the generator duct and auxiliary equipment have led to the position where engineering solutions exist for all of the major problems in an open-cycle installation. This has led to the announcement by the USSR of the construction of a pilot plant of about 75 MW electrical output. This plant, known as the U-25, is located on the outskirts of Moscow and is expected to begin operation in the spring of 1970. It is fired with natural gas, includes all of the components of an

MHD steam cycle and has an MHD generator with an output of 25 MW. A model of this installation is shown in Figure 14.

The application of MHD to base-load power generation has been the goal in the development of commercial MHD generators and is a project of long-range national importance. The incentive for the past ten years of intensive and successful research and development work has been the realization that the demand for electrical power continues to increase, with doubling times of 10 years or less now being common in many countries. The generation of this electrical power is presently accomplished using a steam Rankine cycle with turbo-machinery to perform the necessary thermal-to-electrical conversion. Such systems were first introduced 60 years ago and their evolution has been towards more efficient and/or lower capital cost operation to achieve and maintain a favorable economic position. These improvements have generally been achieved by adopting higher temperatures and pressures to boost overall efficiency but this line of development has, for all practical purposes, now come to an end. Recent experience has shown that the relatively small gains in efficiency which have been attained by temperature and pressure increases to ultra-high levels have not been overly successful from an economic viewpoint.

The economic attractiveness of open-cycle MHD for bulk generation of power from fossil fuel has been indicated in many design studies and cost estimates of conceptual plants. While the actual savings can only be conjectured at this stage, a potential fuel saving of $11 billion between 1985 and 2000 was estimated in a recent Office of Science and Technology Report on the future of MHD.[17]

Coal is by far the most abundant fossil fuel and thus the major energy source for fossil fueled MHD central station power plants. Before large coal burning central station MHD power plants can become commercially viable, it will be necessary to undertake the construction and operation of a prototype or demonstration plant. Such a demonstration plant, which might have a capacity of from one to a few hundred megawatts, would be an important stepping stone to full scale MHD base load plants of several hundred or thousands of megawatts capacity. It would demonstrate the technical and economical feasibility of bulk generation of MHD electrical power generation from coal.

Valuable experience and engineering data for the construction of a demonstration plant can first be obtained from the operation of a long duration experimental MHD generator with coal as the fuel. The scale of such an experiment must be of sufficient size so that it can provide meaningful engineering data for the design and construction of a demonstration plant.

The research and development work thus far undertaken on MHD generators is depicted in Figure 15 with particular reference to the Avco Program. In cooperation with a group of utilities* and

*Allegheny Power System, Inc. through its subsidiaries, American Electric Power Company, Inc. through its subsidiaries, Boston Edison Electric Company, Central Illinois Light Company, the Dayton Power and Light Company, Illinois Power Company, Indianapolis Power and Light Co., Kansas City Power and Light Co., Louisville Gas and Electric Co., United Illuminating Co. and Union Electric Company.

with contract support from the Department of Defense, important experience has been gained with large generators operating at significant power densities. In parallel with this effort, small-scale, long duration development has yielded important information and experience on the design and construction of all components of an MHD power system. Since the large generators have been operated for quite short times while the long duration experiments are at a power level of 10 kW, it is appropriate to depict their historical development respectively along the ordinate and abscissa of Fig. 15 in which logarithmic scales are used.

The development of coal burning generators, as indicated in Fig. 15, should continue upward from the time axis towards the ultimate goal of a base load MHD power plant. This path will concentrate upon the aspects of a base load plant specifically related to the use of coal, including generator development, combustion, high temperature regenerative air preheat, seed recovery and pollution control.

An immediate need which MHD generators can meet is the provision of large reserve units. Experience with the MARK V and LORHO generators has already established the technological base from which MHD units could be developed to substitute for spinning reserve against unforeseen peak conditions or the loss of large sources of power such as large units or transmission lines. An MHD plant is ideal for such reserve since it can readily be designed for a one-to-five second starting time which means it is available when needed without being held in operation and can maintain the dynamic response of power systems, has a very low capital cost, and can remain in operation until after the peak or unit other reserves have been mobilized. Referring again to Fig. 15, existing experience with large liquid fuel generators operated with oxygen enrichment provides the basis for an immediate start on the development of MHD generators for emergency and peaking applications. Power output and operating time can be extended in a demonstration peaking unit of between 50 and 200 MW electrical output. In addition to fulfilling the need for emergency and peaking power, this development will complement the work envisaged on coal fired MHD generators and help to bring central station base load plants closer to reality.

ACKNOWLEDGEMENT

Figures 6 (U-02 facility) and 14 (U-25 pilot plant) were kindly provided by Dr. V. A. Kirillin, Deputy Premier and Chairman, Committee for Science and Technology, USSR and Professor A. E. Sheindlin, Director, Institute for High Temperatures, Moscow.

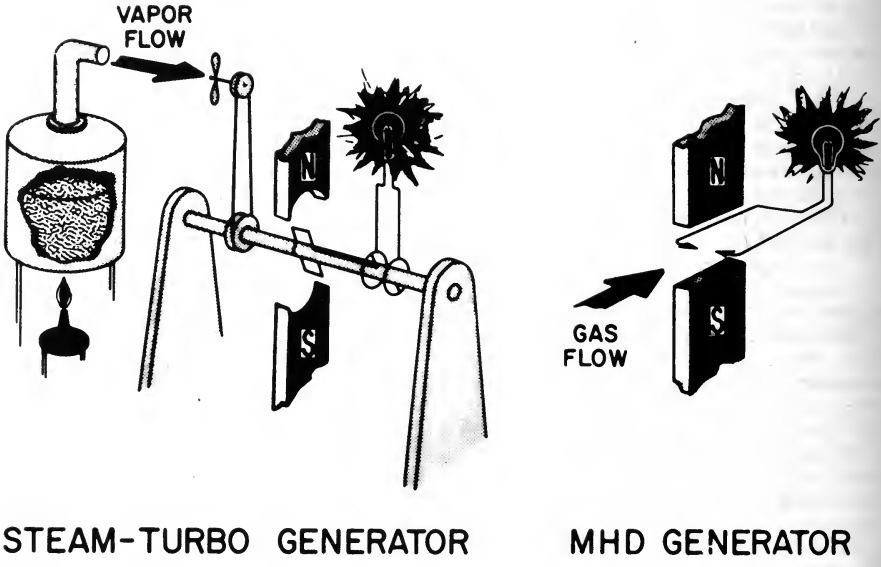


Fig. 1 Principle of MHD Generator

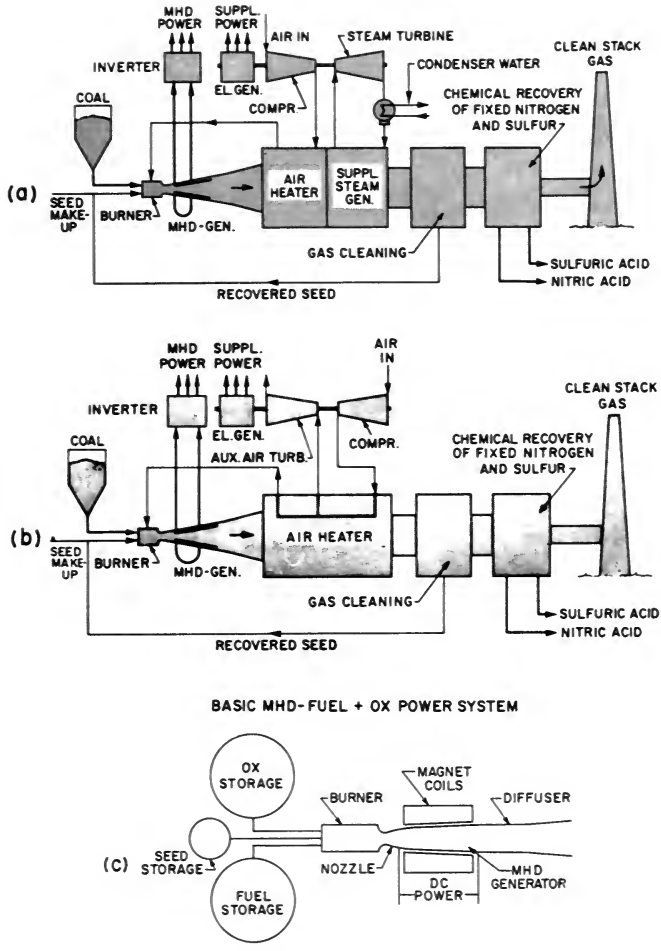


Fig. 2 Open Cycle MHD Power Generation Systems

a) MHD Generator with Associated Steam Cycle

b) MHD - Brayton Cycle

c) Basic System with Liquid Oxygen

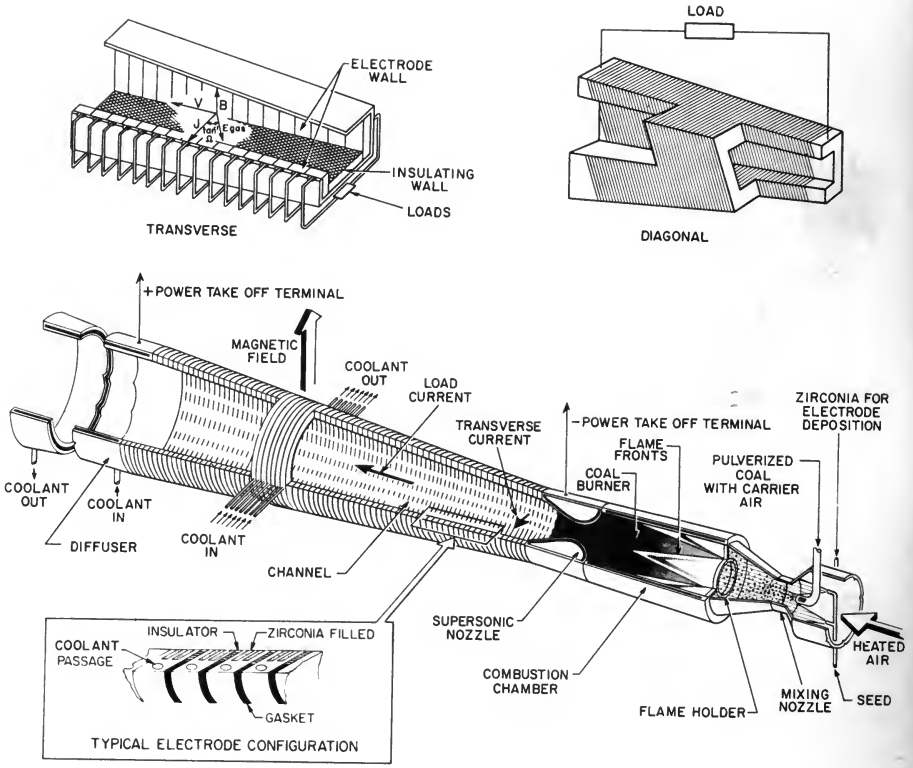


Fig. 3 Coal Fired Generator with Various Channel Configurations

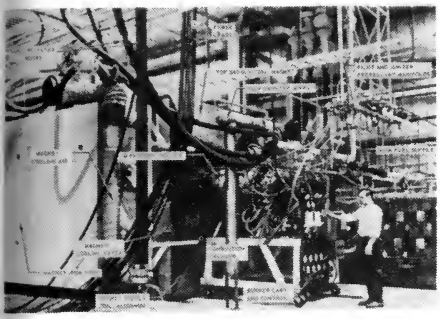


Fig. 4 LORHO Pilot MHD Generator Installation, Arnold Engineering Development Center, Tullahoma, Tenn.

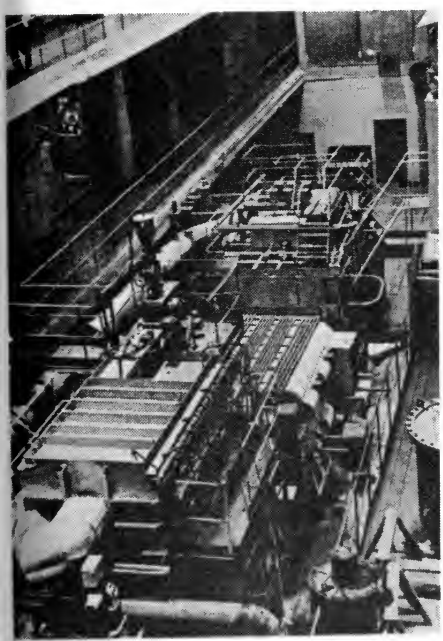


Fig. 6 U-02 Long Duration Installation, Moscow, USSR

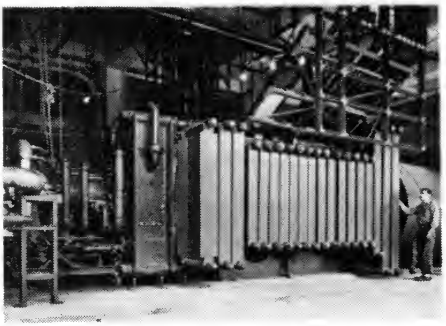


Fig. 5 Mark V Self-Excited Generator

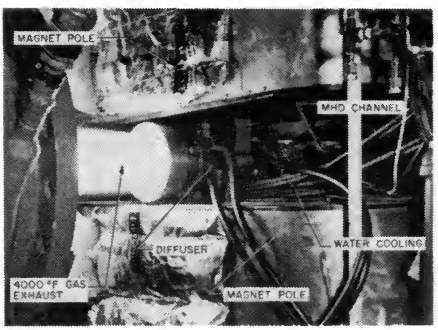


Fig. 7 Avco Everett Long Duration Test Facility

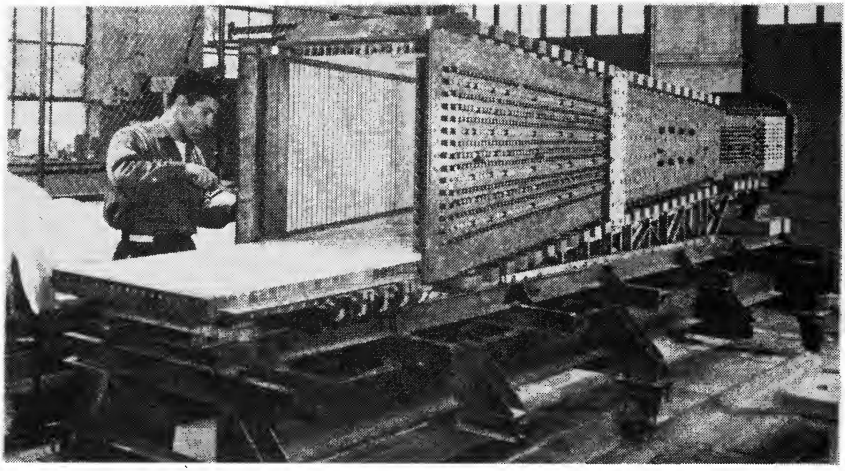
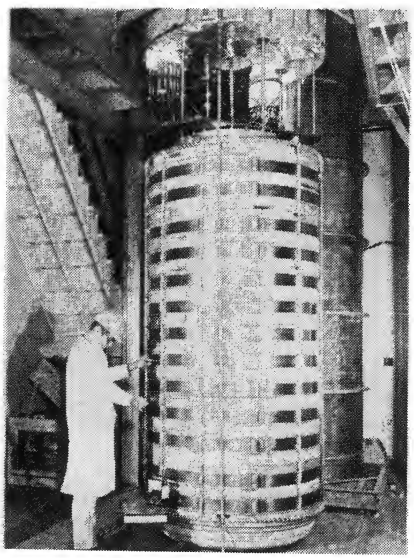


Fig. 8 MHD Channel for Mark V Generator



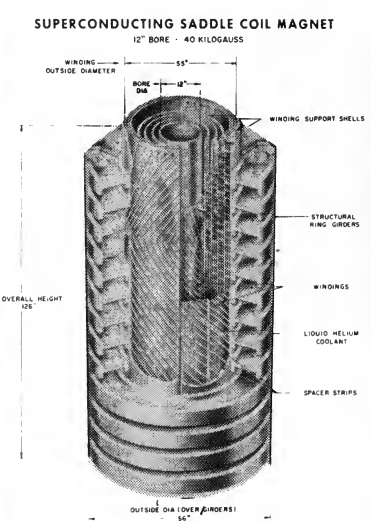


Fig. 9 4 Tesla, 12-Inch Bore Superconducting Saddle Coil Magnet

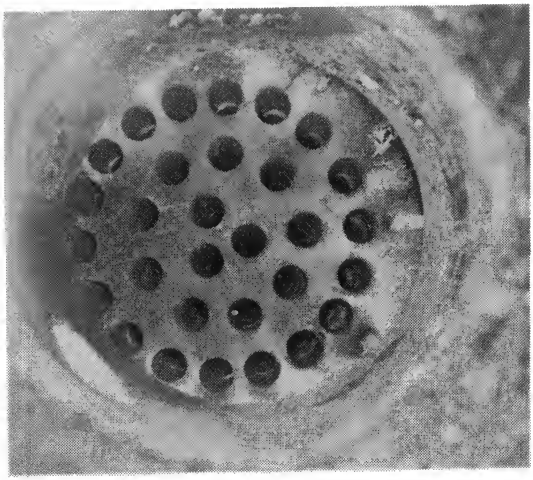


Fig. 10 High Purity Magnesia High-Temperature Air Preheater

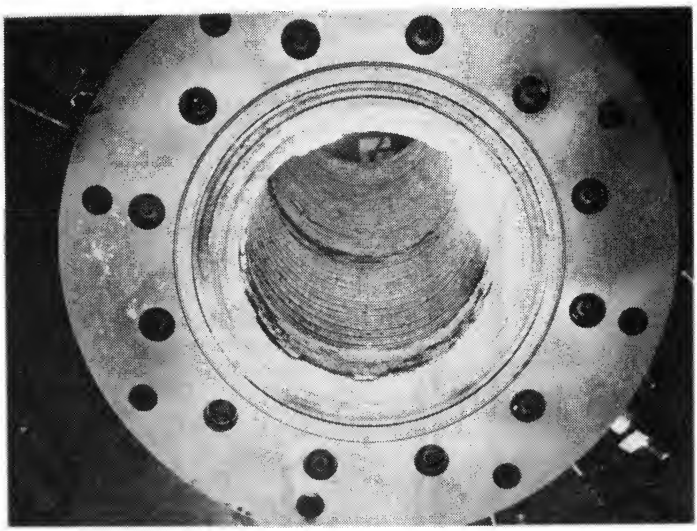


Fig. 11 Interior View of MHD Generator Duct after 200-hour Duration Test

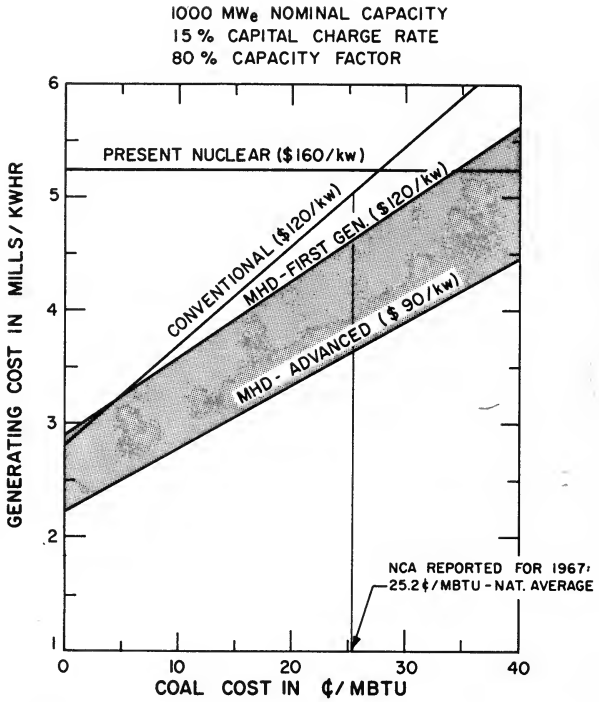


Fig. 12 Comparison of Electricity Generating Costs

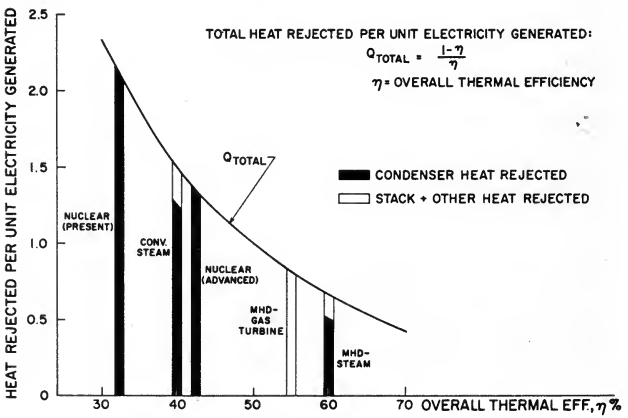


Fig. 13 Comparison of Heat Rejection from Thermal Power Plants

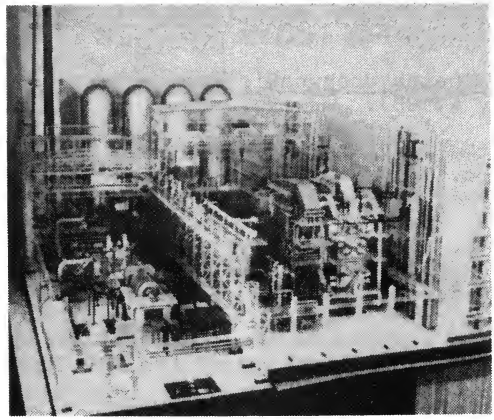


Fig. 14 Model of U-25 MHD Pilot Plant Under Construction in Moscow, U.S.S.R.

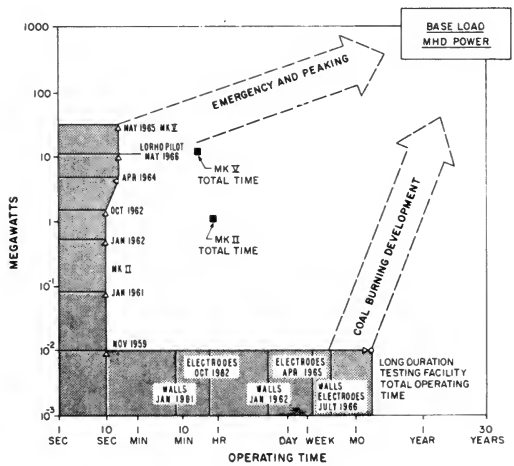


Fig. 15 Past and Possible Future of MHD

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ENGINEERING ASPECTS OF MAGNETO HYDRO DYNAMICS (MHD)

Kenneth A. Roe

Previous speakers have developed background for you on what MHD is and where its development stands today. In addition, the speaker just previous has described a power system including an MHD generator that produces power and also is a part of a hydrocarbon and fuel manufacturing complex. This could be the initial step in using MHD generated low cost energy as the basis for the careful and systematic development of Agro-chemical-industrial complexes throughout the world in the latter part of this century. These plants, to be discussed later, would produce an even broader range of products than those of the petroleum product manufacturing center described by our last speaker.

My purpose today is to view MHD and its application from the viewpoint of an engineer who could be a designer and builder of such systems. I will also discuss with you how I would anticipate that such systems would impact on an electric utility and how its staff might prepare themselves to include such a facility in their system.

The last several decades of scientific innovation have produced many ideas that have great attractiveness and that challenge and stimulate our imaginations. MHD and the applications of MHD that our panel are discussing are perhaps the most interesting and provocative of these ideas. We must always temper our enthusiasm with a good dose of realism because the pot of gold at the end of this rainbow is so rewarding.

Therefore in this examination and over-view, it must always be remembered that MHD is still a developing technology. All of its problems are not yet solved. We are at a stage in MHD development, however, where the chance of economic solution to these problems can be viewed with some optimism. At this time, many of the advantages of the power system using MHD generation are becoming increasingly clear; as are many of the problems to be solved and new requirements to be met by the utility having such a plant in their power generating system.

In this paper we will look at a few of the characteristics of the MHD system; some of the problem areas; some of the advantages; typical application in the power and non-power area; and some of the types of installations.

FACTORS THAT AFFECT POWER PLANT AND SYSTEM DESIGN

A. Size of MHD Power Generation Units is of major importance in their application to a power system. At this time, there seems to be no reason to expect an upper limit on unit size that would limit application of MHD power generators to power systems. Indeed their efficiency is presumed to increase as the unit size gets bigger.

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Their minimum operational size is conviently not too big for application as peaking units.

B. Their effective temperature range of operation of MHD generators is important in determining their place of application and operational characteristics. MHD is inherently a high temperature process. Consequently, it is a high efficiency process (fuel efficiences of 50% to 60% seem feasible).

C. Power Costs for electrical energy made from MHD associated power systems are expected to be low due to the high efficiency of energy and carbon usage. In the case of multiproduct plants associated with MHD, many fixed system costs can be shared by products other than electricity so that power costs should be even lower. Unlike nuclear plants that have high capital costs and high fuel expenditures that must be financed at the time these plants are first built, MHD associated plants will probably not be much, if any more costly than normal fossil fueled plants and the fuel can be financed and purchased as required.

D. The Products -- power and non-power -- from MHD associated plants have an important bearing on the present and future applications of MHD. Since exit gas temperatures must be high, MHD generators must be applied as a "topping system". Gas turbines and steam turbines could be suitable partners to extract the lower temperature energy left in the MHD effluent gas.

An MHD generator generates Direct Current. If it is arranged in a cycle with a gas turbine or a steam turbo-alternator, this part of the combination will generate Alternating Current. If only AC is marketable, the DC can be inverted to compatible AC.

EHV Direct Current Transmission is now a thing of the present. However much RID effort will be required to match the MHD generated voltages in the KILOVOLT RANGE with the EHV DC Transmission Voltages in the MEGAVOLT RANGE.

However, in the large units forecast for the future, the availability of DC could be quite valuable as an attraction for industry to the MHD plant area. Some of the products that might be produced with this DC are caustic and chlorine, electrolytic hydrogen, aluminum magnesium and electrolytic steel, provided economical feasible ways can be found to suitably match the voltage characteristics of the MHD generator and the process.

E. Many hydrocarbon fuels such as natural gas, heavy petroleum residues and the various forms of coal can be used to "fuel" an MHD generator. However, in this Montana area, a major advantage of such a system would be its possible application to coals and lignites. This could make them economically competitive fuels for a long period of time. These fuels could be a source of reformed coal and a range of useful petroleum products in addition to providing MHD fuel.

F. With the addition of a few chemical raw materials, it is technically feasible to make a wide range of chemical products. However, the economics of production and saleability of these products must be very carefully studied.

G. In some coals, quantities of U_3O_8 occur. Where this is so, the economics of its recovery should be studied.

H. Finally, sulphur often present in the fuels used and nitrogen present in the gas traversing the MHD generator produce oxides that I believe must be removed from the MHD system. They ultimately may also provide products having some value.

I. The potential availability of process steam and hot effluent gases can be useful (as a raw material) in the multiproduct plant or for heating or drying application located near the plant.

AREAS WHERE MHD WILL HAVE AN IMPACT ON A POWER UTILITY HAVING SUCH A UNIT IN THEIR SYSTEM

There are problems yet to be solved and new requirements that utility systems must meet when an MHD plant is included in their system. Many of these, however, are not completely and quantitatively assessible at this time. Let us look at some of these.

A. By its very nature, MHD is not an economically complete power generation system in itself (the only exception to this is the peaking application of MHD). Consequently, it must be combined -- to maximize economy -- with another generating system, such as a steam or gas turbine power system. Hence, the MHD process applied to a baseload power plant essentially makes such a plant a hybrid power generating plant.

B. Such combined systems obviously require more competent staff in operation and generation management than would be required by a simple conventional system.

C. Equipment redundancy may also be desirable so that in an emergency when one or the other of the hybrid system components are out of operating schedule, peak generation or emergency requirements can be met by the operation of the other component.

D. Startup, operation and shutdown procedures will probably be more subtle and sophisticated than for a conventional plant.

E. Current utility staffs must be augmented by technicians specially trained in MHD technology and maintenance.

F. Additional specialized maintenance parts must be procured and stored and specialized maintenance facilities must be available to service MHD units.

G. New systems unique to MHD technology such as the seeding system and the cryogenic system for the magnet must be added to the roster of new things to be handled in a routine manner by the utilities.

H. Design, operation and maintenance of MHD associated systems are different and, in some cases, more complex than their equivalents in a normal fossil fueled power system.

For example, MHD, to be efficient, must be operated as a very high temperature process. High temperature processes are often difficult to sustain in uninterrupted operation. This may be particularly true with application of early MHD units when many unforeseen "bugs" may need to be worked out.

I. High temperature processes are often also high maintenance cost processes. The potential presence of oxides of nitrogen and

sulphur combined with the possible thermal cycling of the gas throughput in the MHD generator could make the whole system susceptible to accelerated maintenance. Actual operation in a utility system will provide the opportunity to finally debug and prove out this system.

J. Under conditions of continuous operation and seeding system and the dynamic hot gases within the MHD generator may introduce problems of their own. Problems such as the method of seed feed, chemical reactions occurring while the gas passes through the MHD generator, chemical reactions between the gas and the walls of the MHD generator, reaction between the seeding compound and the electrodes, and the probability of chemical action between the chemicals fed into the system to regenerate the electrodes and the balance of the system are all potential problems in the design of the MHD generator.

K. In the seed system, the problem of seed high efficiency regeneration and recovery as well as the problems of solid to liquid to gas to liquid to solid phase changes that the seed chemicals undergo may provide problems yet to be solved.

L. Air heaters, with their continuous temperature cycling will require special training for utility operators since their design operation, and materials of construction will be different from air heaters customarily encountered in the industry. The proper design and experience with the operation of this equipment will minimize these problems. Longterm use in an operating utility system will confirm final material selection and design parameters.

M. The fuel air mixture versus required air preheat temperature will be an area requiring special design and operator attention.

N. The cryogenic magnetic system will impose operational problems not normally faced by utilities.

O. Electrode development has so far seemed to have successfully solved many potential problems. Long term electrode operational reliability and satisfactory maintenance costs need to be improved. They must be finally established beyond doubt in a plant of significant size operated under normal utility conditions.

P. Material selection and methods of sidewall construction should be evaluated and tested under operating conditions.

Q. Since various fuels, each having their own unique set of advantages and problems, can be used for MHD generators at this time, each fuel type should be evaluated and conditions of application optimized for use with the several types of MHD plants that could be applied to a utility system. Proper fuel selection so that each early MHD installation functions well will be important in building confidence in this method of power generation.

R. The availability of both AC and DC output from a combined plant make possible the building of power load for those customers who uniquely need either current. The need for reliable supply for these two types of service can cause equipment redundancy to guarantee reliability of either supply.

S. Although it is often easily overlooked, the problem of providing low cost high reliability inverter equipment for transform-

ing the DC current to AC for application to large scale MHD generation requires further attention. This large scale equipment should be proven under actual utility operating conditions.

T. Because the MHD associated plants are somewhat more complicated and include application of newer technology, they will take longer to schedule through design and construction and startup than we customarily allow for conventional fossil-fueled plants. In the end, their costs may, perhaps, be slightly higher than their simpler counterparts, especially for the early units.

U. System performance under partial load and load cycling conditions are essential to finally testing and proving out the application of MHD to utility power generation systems. It is assumed that MHD generation systems have low system inertia and so can respond easily to power load changes. The facts on this point are important and may be critical to application of MHD.

V. It is probably less of a problem for plant operating personnel to learn to handle the fuel and combustion processes of an MHD plant than to train for similar service in a nuclear plant. In addition, they run no rish from hazards of radiation.

W. The commercial factors applying to MHD associated plants -- particularly multiproducts MHD associated plants -- like multiproduce costing and pricing will pose problems to the operating utility, its customer, and the federal and state regulatory bodies that the utilities are accustomed to dealing with.

ENVIRONMENT CONSERVATION ADVANTAGES RESULTING FROM APPLICATION OF MHD TECHNOLOGY TO POWER SYSTEMS

The environmental effects and the public acceptance of MHD associated plants will be important factors in their application. Should they produce fewer environmental problems than other power generation systems, this fact will provide additional incentives to apply MHD technology to power generation.

One MHD application which presents interesting and economical potential is its combination with a gas turbine -- where minimal coolant water is needed. Application of this hybrid cycle to arid regions or areas where thermal pollution of water is serious could make MHD associated plants desirable.

Because of the high cycle efficiency, a smaller percentage of available heat in a unit of fuel is wasted to the heat sink in an MHD associated plant. Consequently, there is less thermal pollution per unit of electricity produced. This is in direct contrast to our current generation of nuclear plants where lesser cycle efficiency causes greater thermal pollution per unit of electricity produced.

Unlike nuclear plants, MHD plants produce no radioactive wastes and potential owners of MHD plants probably will not need to face related problems of waste disposal and public acceptance. The expense and uncertainty of AEC review and licensing procedures may well make MHD associated plants simpler, quicker and less expensive to build than nuclear plants. These plants, unlike their nuclear counterparts, are not continually haunted by the spectre of disaster should some major accident occur.

High cycle efficiency makes the ash produced for each unit of energy output lower so there should be smaller incremental stack dust loading. The possible future need to clean up gases going to the MHD generator and to improve seed recovery economy may probably further cut back on ash quantities traversing the system and also, therefore, being fed into the atmosphere.

Where the MHD generator gas effluent is used as a raw material for chemical product synthesis, the amount of CO_2 per unit of power generated that is fed into the atmosphere is much smaller than for normal fossil fueled plants. This should be helpful in obtaining the public acceptance of these multi-produce MHD associated plants of the future -- since the disadvantages of CO_2 atmospheric pollution is receiving increasing attention.

Because of the concentration of the oxides of nitrogen formed at the high combustion temperatures, equipment for their removal must be incorporated. As a result of this, the oxides of sulphur can also be removed resulting in less pollution. In addition, two saleable products could be recovered.

PRACTICAL APPLICATIONS OF MHD TO POWER SYSTEMS

There are three types of MHD associated plants that I would like to direct your attention to in order to illustrate some of the interesting characteristics of these MHD applications. These three types of plants are the peaking plant, the open-cycle MHD base load hybrid power plant, and the multi-product MHD associated plant.

THE PEAKING PLANT

The peaking plant application of MHD is probably the simplest of these plants as far as the pieces and nature of equipment involved is concerned. The economic requirements for peaking or emergency power are such that low capital cost is increasingly important and high efficiency is much less important. Units must be available in sizes ranging from ten to hundreds of megawatts. Minimum manpower should be required. Rapid start-up and shut-down and on line availability are essential. Maintenance costs during stand-by periods must be minimal.

It would appear that the rocket-type MHD plant would satisfy these requirements. The capitalized cost of this simplified MHD plant would be much lower than a baseload plant, but its operating cost might be too high for other than emergency application. Factors such as:

a. low thermal efficiency

b. cost of liquid oxygen

c. the possibility of losses or high cost of unrecovered seed

may make application of such equipment to peaking marginal.

Figure 1 shows the economics of MHD and other alternate types of peaking plants. This figure confirms that the economics of such peaking plants are marginal. Since cost factors for MHD plants are not yet firm, perhaps this type of plant should receive further attention and study. Even a trial installation may be

justified to prove out such a system.

More promising studies of economic peaking power consider the application of an MHD topper combined with a steam turbine cycle. In this case, the whole unit would be sized so that the topping MHD unit would be used for peaking and would also share part of the base load with the steam plant during off peak periods. This concept is illustrated in Figure 2 where a typical daily load curve for a large utility is shown. The upper portion represents the system's daily peaking demand satisfied in this case by increasing the output of the MHD topper. The bottom of the curve represents the base load generation by a steam turbine operated in combination with MHD. Such a plant appears to show promise of successful and economic operation.

THE BASE LOAD PLANT

The planning of generating capacity additions for an electric utility system must be primarily concerned with providing reliable service at the lowest possible cost consistent with minimum acceptable environmental disturbance. The selection of unit types and sizes for an economically expanding generation system takes into consideration system load and existing units' characteristics along with basic system economic parameters.

The most efficient thermal units serving a system are usually base loaded. Less efficient, older units are relegated to less extensive use. The high efficiency of MHD associated plants would make them attractive as base load plants.

Our studies of MHD system generation economics reveal that a coal fired open-cycle MHD operated in conjunction with a conventional regenerative steam turbine cycle will achieve maximum fuel economy. Such a combined cycle sized for a net output of 830 MW is schematically shown on Figure 3. In this case, a coal fired 330 MW MHD topping cycle was added to a conventional supercritical 500 MW steam electric generating unit. The steam unit is typical of modern, high-efficiency power stations such as Fort Martin Station of Monongahela Power Company completed in 1967. Feasibility of a combined MHD cycle has been documented by many studies and is now being demonstrated by Russians in the form of a 75 MW pilot plant currently under construction near Moscow.

Meaningful cost analysis can only be based on the results of detailed plant designs. However, economic assessment of MHD prospects can be based on reasonable evaluation of research data and by comparison of costs of similar structures. Figure 4 summarizes plant performance and generation cost data of alternate types of large, base load electric generating units. Coal fueled generating units are alternately located at mine-mouth or near load center; no such distinction was made for the nuclear unit, since plant location will have no significant effect on nuclear fuel costs.

For performance calculations, the MHD generator was assumed to have gross efficiency of 25 percent. The combined MHD-Steam Turbine Cycle full load efficiency (after adjustments for station auxiliaries) was calculated at about 49 percent. For comparison purposes, all units are assumed to operate at high annual capacity factor of 80 percent, typical of high efficiency base load plants.

The generation cost results are seen to strongly favor MHD over conventional fossil and nuclear fueled generation. The mine-mouth, base loaded MHD plant shows the lowest unit generation cost of all alternate cases considered. Evidently, this is the result of significant fuel cost advantages of MHD over all its competitors, including nuclear fueled generation.

THE MULTI-PRODUCT PLANT

The concept of a multi-product plant has grown out of the realization that the low cost energy made available by large MHD associated power systems, coupled with the availability of coal, air, water and the product gases from MHD power generation, with the addition of a few other basic chemical raw materials can be carefully and systematically made the center of production for a wide spectrum of chemical and industrial products.

Figure 5 shows diagrammatically one such plant. This diagram has been simplified and drawn to highlight the relation of the MHD power complex to the balance of the multi-product plant.

Such a system involving the production of such a wide range of chemicals, yields a set of highly inter-related products and chemical intermediates from which the product output of the complex may be selected. Proper selection of these products is a complex problem and the rewards for a proper selection or the penalties for a poor selection are decisive in the ultimate economic viability of the multiproduct plant. It would be necessary to design as much flexibility into the complex as possible so that product changes could be made from time to time as market conditions dictated. These complexes must produce products that can be made from easily available or inexpensively transportable chemical raw materials in the area in which the multi-purpose plant is located.

This is perhaps the most fascinating of all the applications of MHD because it has so many challenges and so many economic rewards for successful designing and managing of such a system.

Let us turn for a moment and examine a few of the characteristeristics inherent in such a system.

The organization of management of this complex and directing its inter-relationships will require great technical and executive skill. The coal preparation plant, the multi-fuel preparation and manufacturing plant, the chemical products plant, the metallurgical products plant, and the petroleum products plant all will require a wide range of technical know-how and skill unique to themselves.

For this reason, it would probably be unwise to expect the utilities to undertake the overall responsibility for managing the entire complex and it should probably limit itself to the possible supply of the following products to the chemical, metallurgical, and petroleum complex and its own fuel storage and auxiliary power supply and power to its own external markets. The maximum number of products which would have to be supplied by the utility might include:

1. Effluent gas from the MHD generator
2. Process steam, possibly at several temperatures

and pressures

3. AC power
4. DC power

Compared to the product output of the non-power portion of the mutliproduct plant, this roster of requirements looks simple indeed. However, a little thought will indicate that supplying each one of these products possibly to meet production schedules, while supplying the external load outside of the multi-product plant will pose dispatching and operational problems more difficult than those usually experienced by most utilities.

It is unfortunate that time does not permit a more detailed examination of the fascinating decisions that must be made and the parameters that must be selected, the alternates that must be evaluated -- it is a challenging type of multi-product plant.

I do not wish to leave the impression that this opportunity is available to us tomorrow. Indeed, this is a matter that is receiving a good deal of thought and attention by long-range energy and resource planners. Their time scale for such plants is late in this century, and their approach is that there are many places in the world which could support these so-called agro-industrial-chemical complexes, which would be located near an energy center that could provide the low-cost source of energy required for these highly energy-oriented industries.

The Oakridge National Laboratories has pioneered in these studies especially as they apply to the use of nuclear power and desalting technology. A number of tentative locations in the world have been selected for more careful study. At this time, a pilot location in Puerto Rico has been picked to be used as a basis of detailed economic feasibility studies. My company is fortunate in having been designated as the company that will undertake a detailed study of this problem.

From what we can see, there is no reason why the use of MHD as an energy converter as outlined above could not be feasible if not very desirable in such a situation. Since the expected application of this concept could not be expected to occur until late in this century, it would appear that sufficient time is available for development of the needed MHD technology -- providing work is undertaken at an increased pace.

Again, I must caution that it is necessary -- especially in this imagination-stirring area -- to remember that the cataloging of intriguing possibilities is many giant steps away from the making of such a plant into a smooth-operating, economically viable reality. This type of plant is possible, but the road to success must result from hard work and availability of a good deal of money.

A FORWARD VIEW

Although many problems have been called out in the text above, there would seem to be good odds that they can be successfully solved. Consequently, a thoughtful evaluation of the situation indicates that there is a real need to and a real reward to society for a successful development of MHD.

When we look at the state of the art today, it is clear that MHD technology requires additional research and development. The areas that have been indicated above are some of these requiring special attention. It should be remembered that in any of the major applications of MHD discussed above, it is necessary that the equipment be able to operate satisfactorily for long periods of time under conditions encountered in a utility system and/or a chemical plant. To date, in the megawatt size range, such long-term operation has not been achieved. For this reason, an intensive program of research and development work to make this possible is required. This R and D program should include the early completion of a judiciously sized pilot plant.

In addition, we could take a leaf from the book of nuclear power development in the United States. Once this basic research and development has been done, we will be at a place where a similar time and development of nuclear energy, a commercially-sized nuclear plant located at Shippingport, Pennsylvania paved the way for large-scale nuclear power applications. At an appropriate time, such an MHD plant should be designed, built and located in a utility system to demonstrate the use of this most attractive energy technology. The cost of such a research program and of such a commercial demonstration MHD plant should be easily recovered in overall savings in our future power costs if this system can be made to be a practical part of utility operations.

I urge the adoption of an immediate program sufficiently funded to demonstrate the economic feasibility of MHD.

LIST OF EXHIBITS

Figure No.	Title
1	Unit Generation Costs -- Peaking Plants
2	Typical Daily System Generating Curve
3	Flow Diagram -- Combined MHD Steam Turbine Cycle
4	Unit Generation Costs -- Base Load Plants (Annual Capacity Factor 80%)
5	Multi-Product MHD Plant

Figure 1

UNIT GENERATION COSTS

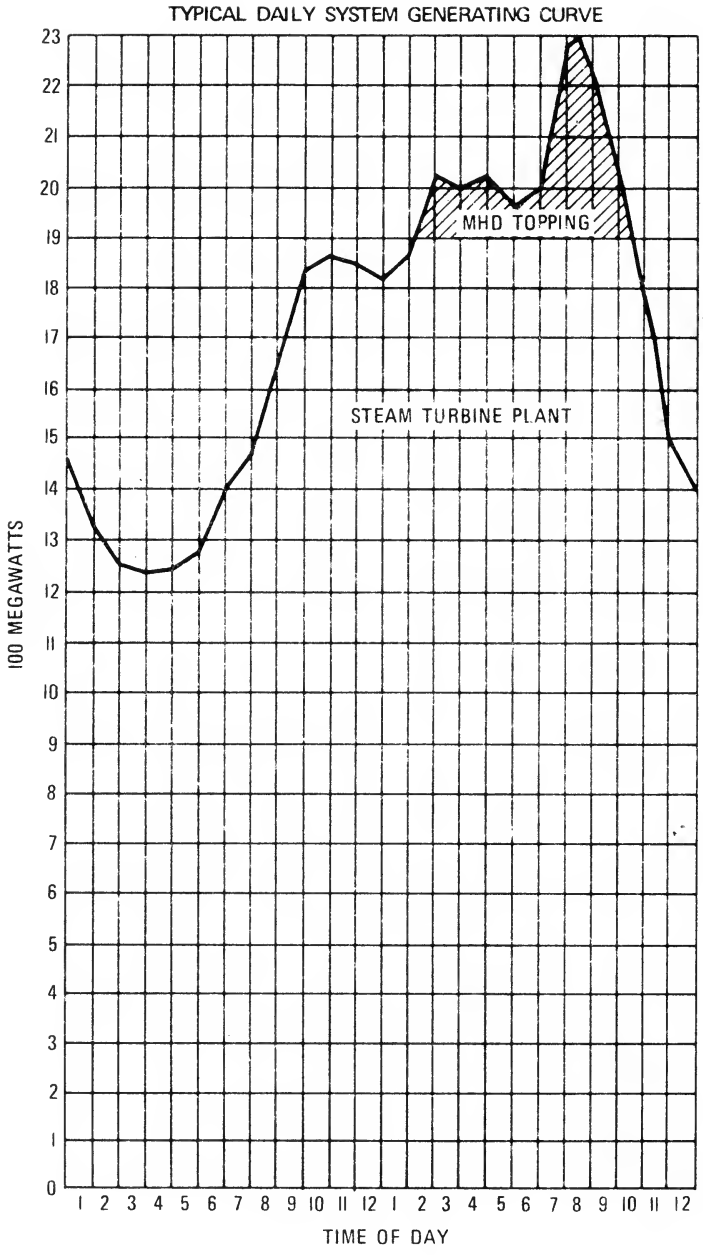
PEAKING PLANTS

Plant Type	MHD**	Gas Turbine	Gas Turbine
Plant Location	Load Center	Load Center	Load Center
Unit Rating, MW	50	50	50
Type of Fuel	Coal	Residual Oil	Light Oil
Unit Fuel Cost, ¢/MBTU	30	30	75
Overall Plant Efficiency, %	18*	26.2	26.2
Net Plant Heat Rate, BTU/Kwhr	19,000	13,000	13,000
Installed Plant Cost, $/KW	170	130	100
Unit Energy Cost, Mills/Kwhr			
@ 1200 Hrs/Year Full Load Operation			
Fixed Charges @ 10%	14.20	10.83	8.33
Fuel	5.70	3.90	9.75
Operation and Maintenance	1.00	2.00	1.00
TOTAL, Mills/Kwhr	20.90	16.73	19.08
@ 3000 Hrs/Year Full Load Operation			
Fixed Charges @ 10%	5.67	4.33	3.33
Fuel	5.70	3.90	9.75
Operation and Maintenance	1.00	2.00	1.00
TOTAL, Mills/Kwhr	12.37	10.23	14.08

*Gross efficiency of 25 adjusted for station auxiliary power.

**Without waste heat recovery.

FIGURE 2


TYPICAL DAILY SYSTEM GENERATING CURVE
MHD TOPPING
STEAM TURBINE PLANT
100 MEGAWATTS
TIME OF DAY
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12

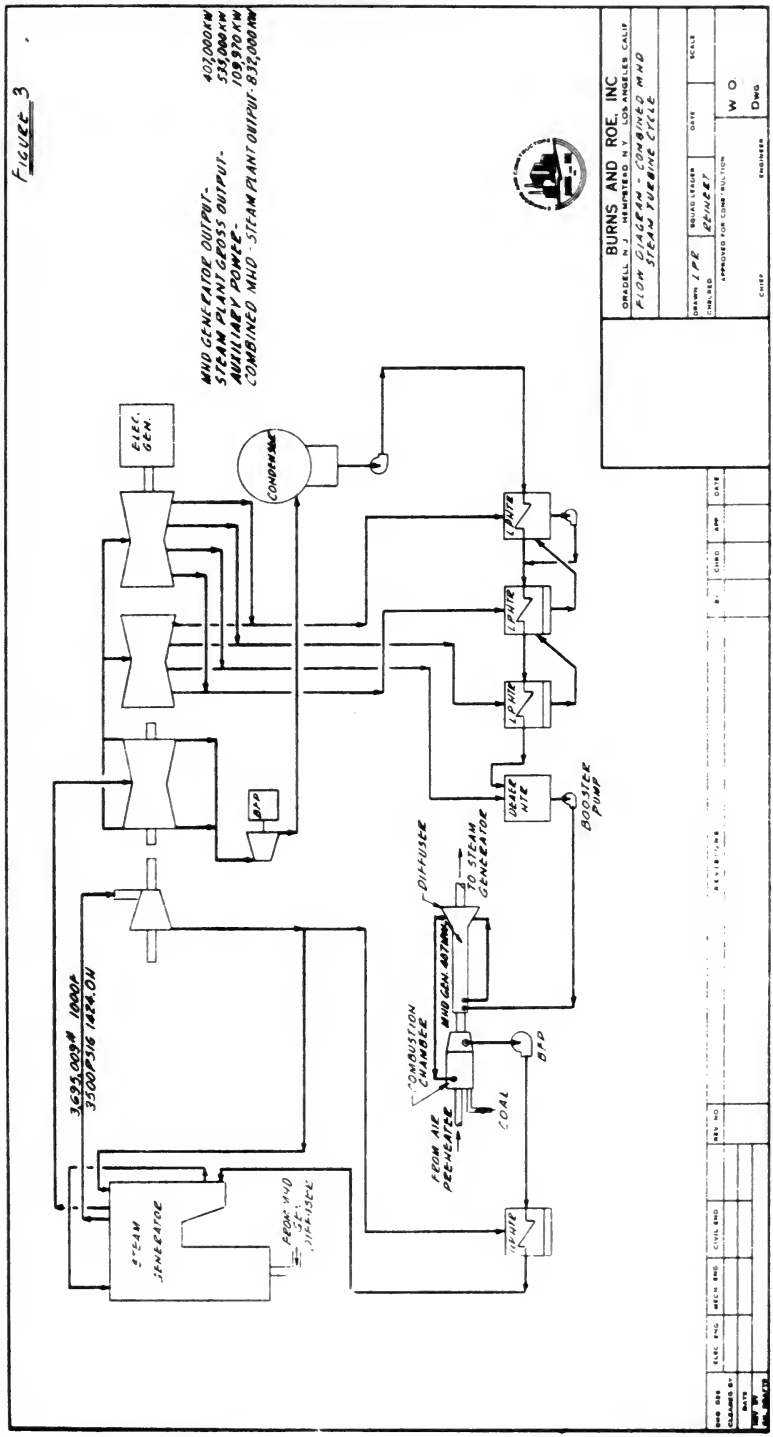


FIGURE 3
MHD GENERATOR OUTPUT- 407,000KW
STEAM PLANT GROSS OUTPUT- 535,000KW
AUXILIARY POWER- 109,970KW
COMBINED MHD - STEAM PLANT OUTPUT- 832,000KW
BURNS AND ROE, INC
ORADELL N J HEMPSTEAD N Y LOS ANGELES CALIF
FLOW DIAGRAM - COMBINED MHD STEAM TURBINE CYCLE
DRAWN LPR
CHECKED
APPROVED FOR CONSTRUCTION
CHIEF
ENGINEER
SCALE
DATE
W O
DWG
ELEC. GEN.
CONDENSER
L P HTR
DEAER HTR
BOOSTER PUMP
BFP
DIFFUSER
TO STEAM GENERATOR
MHD GEN. 407,000
COMBUSTION CHAMBER
FROM AIR PREHEATER
COAL
3,695,009# 1000F
3500PSIG 1424.0H
STEAM GENERATOR
FROM MHD GEN. DIFFUSER
REVISIONS
REV NO
CIVIL ENG
MECH ENG
ELEC ENG
DWG DES
CLEANED BY
DATE
NOT TO BE SCALED

Figure 4

UNIT GENERATION COSTS

BASE LOAD PLANTS (ANNUAL CAPACITY FACTOR 80%)

Plant Type	MHD-Steam Turbine		Fossil-Steam Turbine		Nuclear-Steam Turbine
Plant Location	Mine-Mouth	Load Center	Mine-Mouth	Load Center	
Net Plant Output, MW	832	832	832	832	832
MHD Generator Output, MW	407	407			
Overall Plant Efficiency, %	49	49	38.2	38.2	33.0
Net Plant Heat Rate, BTU/Kwhr	6964	6964	8910	8910	10,400
Estimated Plant Cost, $/KW	170*	170*	170	170	250
Type of Fuel	Coal	Coal	Coal	Coal	Nuclear
Unit Fuel Cost, ¢/MBTU	19	30	19	30	16
Unit Generation Costs, Mills/Kwhr:					
Fixed Charges @ 10%	2.43	2.43	2.43	2.43	3.57
Fuel Cost	1.32	2.10	1.70	2.67	1.66
Operating and Maintenance	0.30	0.30	0.30	0.30	0.30
TOTAL, Mills/Kwhr	4.05	4.83	4.43	5.40	5.53

*MHD Plant Cost in $/Kw of Capacity
assumed same as conventional steam plant costs.

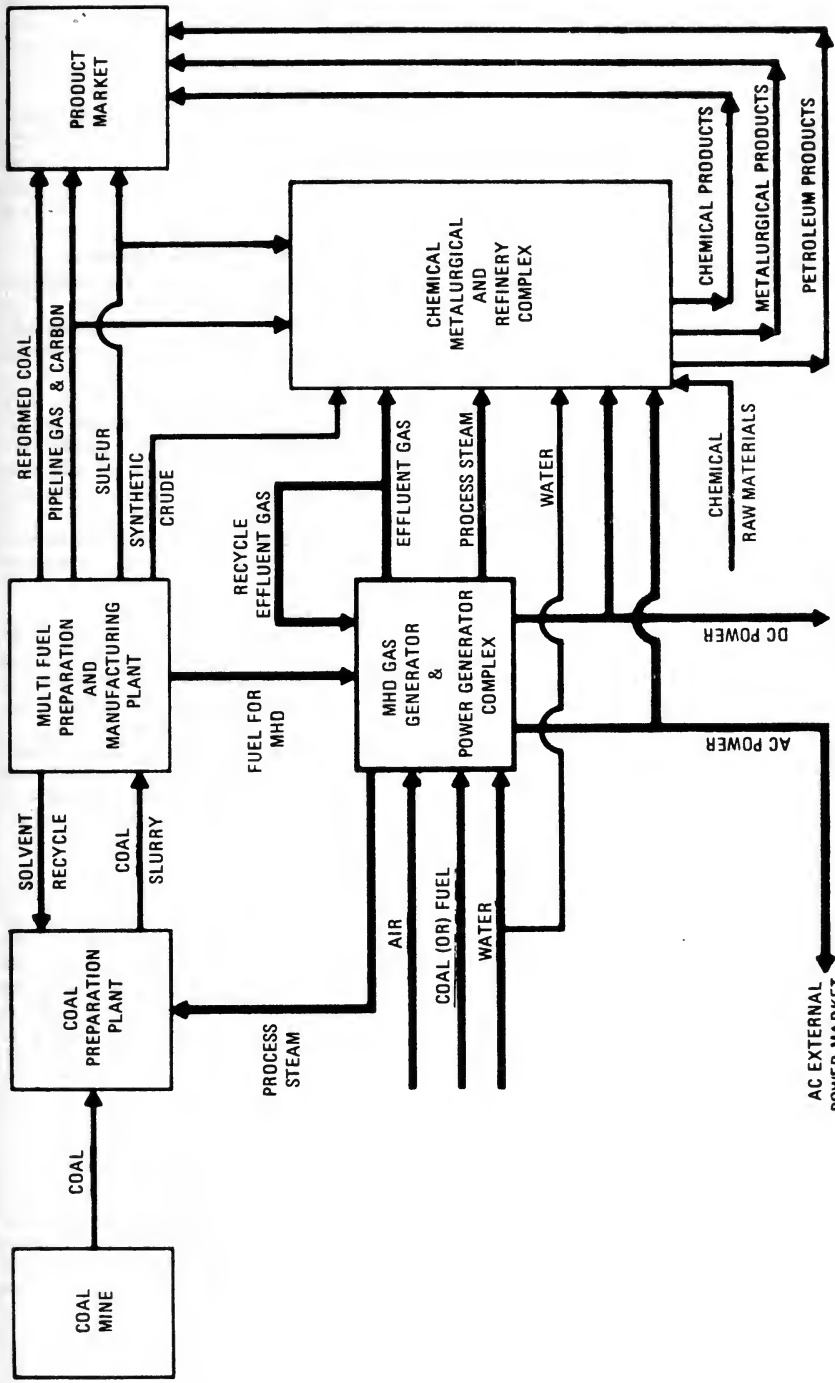

MULTI-PRODUCT MHD PLANT
COAL MINE
COAL
COAL PREPARATION PLANT
SOLVENT
RECYCLE
COAL
SLURRY
MULTI FUEL PREPARATION AND MANUFACTURING PLANT
REFORMED COAL
PIPELINE GAS & CARBON
SULFUR
SYNTHETIC
CRUDE
PRODUCT MARKET
CHEMICAL METALURGICAL AND REFINERY COMPLEX
CHEMICAL PRODUCTS
METALURGICAL PRODUCTS
PETROLEUM PRODUCTS
CHEMICAL
RAW MATERIALS
RECYCLE EFFLUENT GAS
FUEL FOR MHD
MHD GAS GENERATOR & POWER GENERATOR COMPLEX
EFFLUENT GAS
PROCESS STEAM
WATER
DC POWER
EXTERNAL DC POWER MARKET
AC POWER
AC EXTERNAL POWER MARKET
PROCESS STEAM
AIR
COAL (OR) FUEL
WATER

FIGURE 5

PROJECT GAS, OIL, POWER

Prepared by
Neal P. Cochran

Address given by
Norris J. Brunsvold

The Office of Coal Research program for converting coal to liquid fuels, fuel gases, and power is reasonably well known. Two pilot plants for conversion of coal to liquid fuel have been authorized by the Congress. The first unit, Project Gasoline, is now operating at Cresap, West Virginia, containing data needed to design commercial scale plants. The second, equally important plant, is under construction at Princeton, New Jersey, and is expected to be ready for operation no later than the middle of next year. Two pilot plants for conversion of coal to pipeline gas have been approved, the CO_2 Acceptor Project now ready for construction at Rapid City, South Dakota, and the Institute of Gas Technology's Hy-Gas Plant now about 30 percent complete at Chicago. We are continuing our work on Project Fuel Cell in an effort to develop improved methods for converting coal to electricity. Project Fuel Cell is not yet ready for pilot scale development.

The projects that I mentioned are not OCR's total program, but they do constitute a major portion of the financial effort. In the past, we have been forced to abandon our H-Coal Project, our Kellogg Gasification Project, as well as other work because of non-availability of funds. Although work on these projects has not continued, they should be factored into anyone's thinging when considering methods to improve our national use of coal. Equally important is the need to develop methods of power generation that do not contaminate either the local or regional environment.

The status of technology at any given period in time is a product of a multitudinous number of factors, which include (1) public need or desire, (2) the economics of the market place, and (3) man's knowledge and ability. The continued growth of electric power and sale of gas in the energy industry indicates that people need or want more convenient energy forms. Prices in the energy business are determined largely by the availability of the basic energy materials, oil, gas, and coal. Point three concerns man's scientific and engineering "know-how" and it is with respect to this last that I wish to address my remarks.

The history of the oil and gas industry demonstrates a continuous growth in market, this in turn suggests creation of a synthetic fuel industry in the United States. Shortages of gas are near term possibilities, the findings of crude oil are not keeping pace with our national needs for increased energy in the liquid form, and as supplies become more and more difficult to locate the price is rising with respect to the price of coal. The

Neal P. Cochran, U. S. Department of the Interior, Office of Coal Research, Washington, D.C., and
Norris J. Brunsvold, FMC Corporation, Princeton, New Jersey.

OCR program is predicated upon competing with natural supplies of oil and gas and the increasing cost of finding and refining oil and gas are an assist in the program.

I believe that we could, today, project a plant capable of producing gas, oil, and power at low cost from typical coals of the Fort Union deposit. This is not to say that coal from the mid-continent or from Appalchia or the inter-mountain West could not find equal application. Final delivered price in the market place is the ultimate answer. What would such a plant consist of?

The portion of the emerging technology and use of coal I visualize is a plant that consists of a carbonization section that will produce both gas and liquid fuels followed by a hydrogenation to produce a synthetic crude. A crude, I might add, considerably better than the normal run of crude regularly fed to our Nation's refinery today. This carbonization plant will be the first step in an overall scheme that might finally include a refinery. Pipeline gas would be available for sale as well. Char leaving the carbonizer would provide fuel for a power plant. Power would be supplied to the carbonization unit and provide all the power needed to mine the coal, with power available for export also. This then is the first step for an integrated total coal operation to produce the products needed in today's markets, gas, oil, and power.

The second step in my hypothetical regional development would consist of adding a direct coal hydrogenation plant whose product would be brought together with the liquid from the carbonization plant to make additional crude. As in the first case hydrogen would be supplied to the direct coal-hydrogenation plant and to the liquid-hydrogenation plant via the gas production portion of the facility. Unreacted solid coal from the hydrogenation unit would provide a portion of the feed to the carbonizer and in turn to the power plant.

At some later period in time, a crude refinery might be added to the unit to produce motor fuel, diesel fuel, jet fuel, and petrochemical type manufacturing. I would expect such a plant to require about 50,000 tons of coal per day and it would produce approximately 102,000 barrels per day of a synthetic crude. The accompanying power plant would be approximately 1,750,000 kw of which approximately 1,250,000 kw of 30,000,000 kw hours/day would be available for export. Pipeline gas from the pla nt would total approximately 125 million cubic feet per day.

The total plant concept as described is shown on Figure 1. This simple schematic shows coal from the mine fed to a COED plant for carbonization and to an H-Coal plant for direct coal hydrogenation. Liquid from the COED plant and from the H-Coal plant are treated in an H-Oil type operation to produce synthetic crude. The plant gases pass through the gas plant for separation of liquids, manufacture of hydrogen, and conversion of the remainder to pipeline gas. The solid material from the plant passes through the power plant portion for manufacture of plant and mine power and power for export. More of this later.

The COED plant represents results from OCR's work with the FMC Corporation. As visualized here, the plant would consist of three separate stages for carbonizing a typical Montana coal. The unit would be approximately 60 feet in diameter and about 150 feet in

height. In the three stages coal would be heated successively to 600, 1100, and 1600 degrees. Final stage of the vessel would include input of electric power along with steam to produce the necessary gas for volatilizing the coal, producing hydrogen needed by the plant, and for the manufacture of pipeline gas. Because of its low cost, this plant and the power plant should be built first.

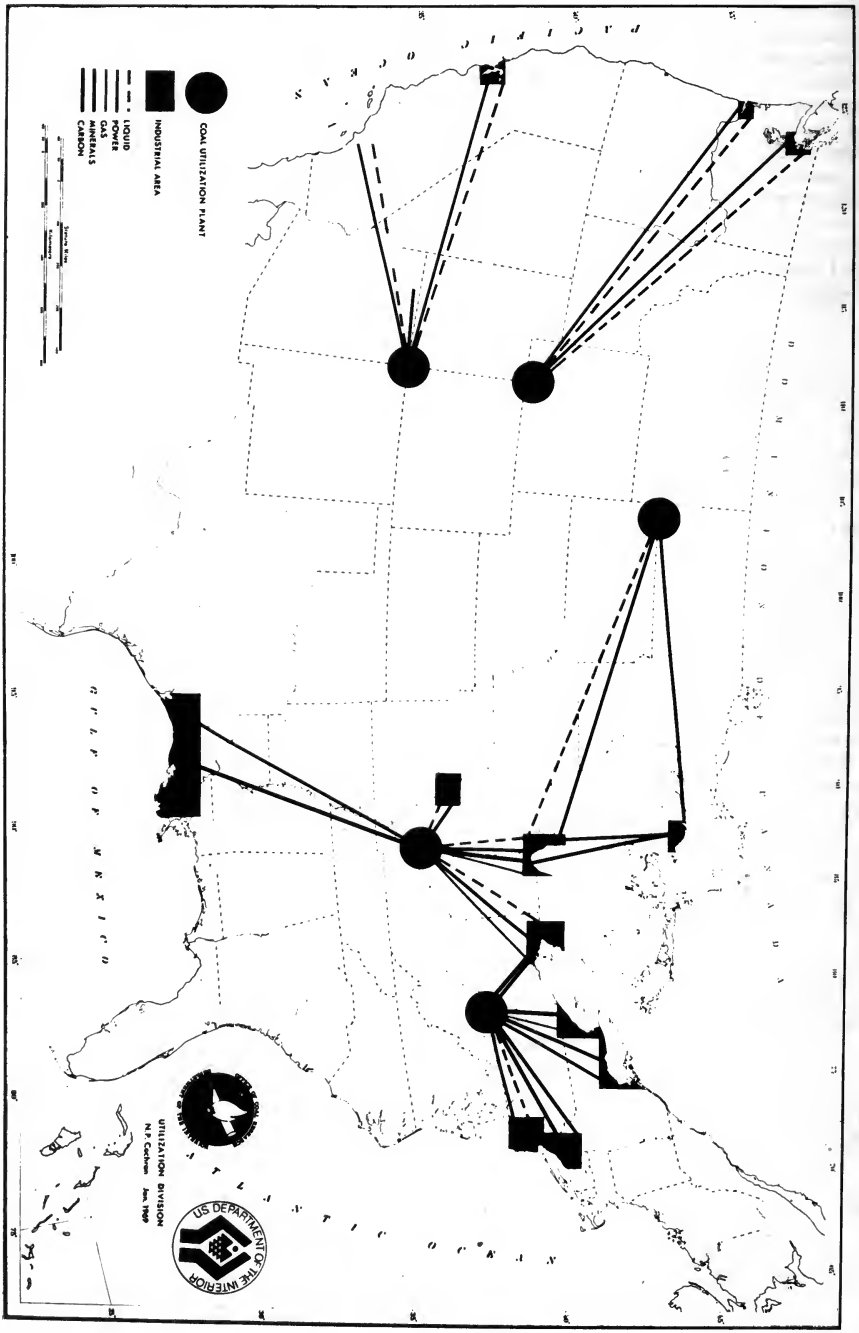
At some later time an H-Coal plant would be added to the unit to produce additional synthetic crude, char, and gas. OCR has not begun pilot development of an H-Coal process as yet, but we have included funds in our FY 1971 budget request to begin. All liquid products from the COED plant and the H-Coal plant would be fed to the H-Oil plant. This is a standard commercially available development representing a better, if not the best, way for upgrading typical coal liquid products.

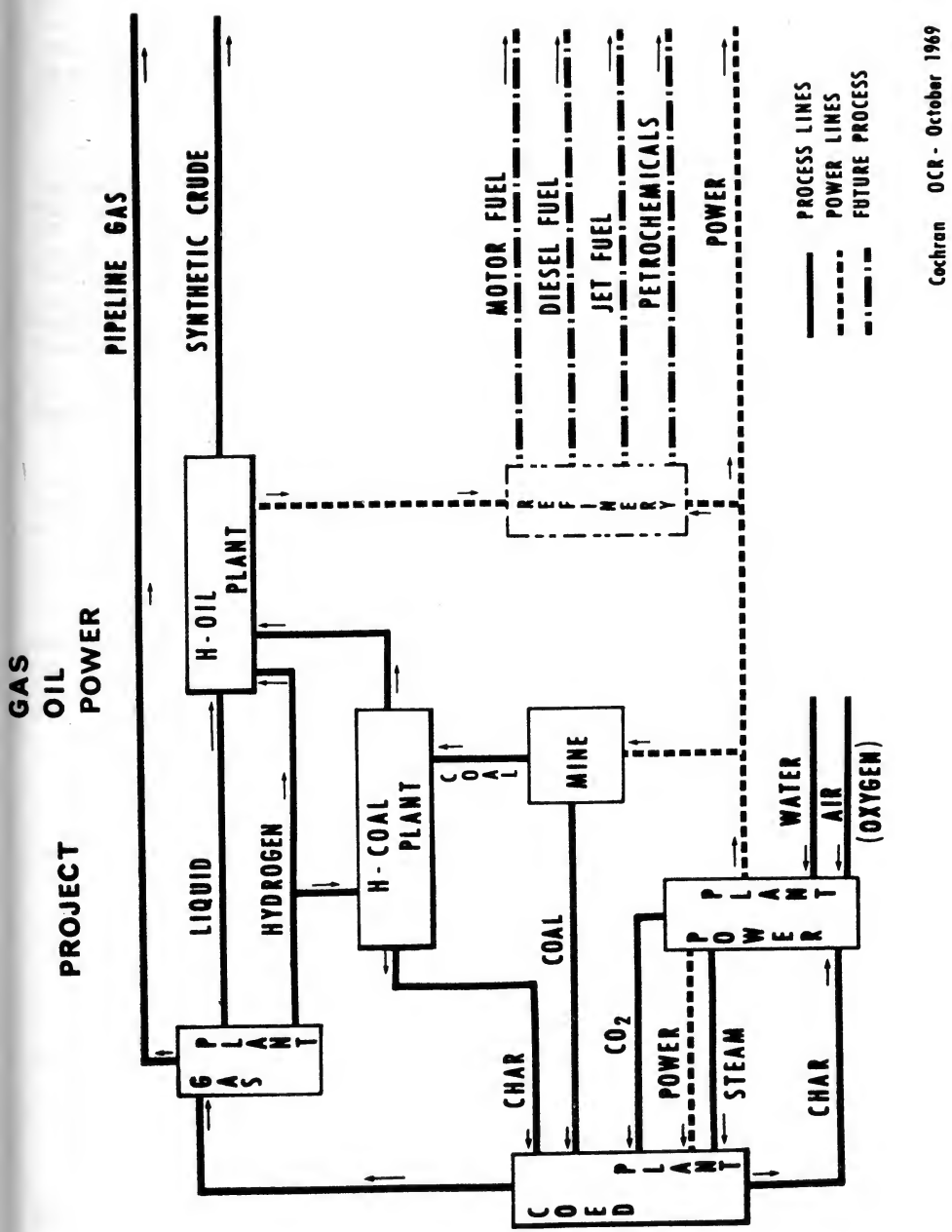
What is included in the power plant? This is a critical portion of the entire concept and we must have improved technology available if synthetic fuel plants are to become a reality. The most likely candidate for this power system, as I view it, is the MHD or magnetohydrodynamic system -- a natural for the Northern Great Plains. Char leaving the COED plant portion of the project -- and we can adjust our COED capacity to fit any conceivable situation -- is sent to the power plant for production of a clean carbon monoxide fuel gas. Please note that I said "clean". All sulfur and other noxious products will remain with tge ash and other materials in the coal in a liquid carbonate melt. This gasifier is a somewhat specialized version of the type OCR had under development with the M. W. Kellogg Company. The carbon monoxide is burned with oxygen from an air separation plant to produce hot CO_2 seeded with potassium carbonate. This hot gas will pass through an MHD generator for production of direct current. A portion of the energy remaining in the hot exiting gas will be used to heat the incoming coal and to produce steam and power and as a reactant in the COED portion of the plant. The balance would be recycled to the gasifier where the CO_2 would be reduced to CO. We would expect the overall efficiency of this combination MHD-steam power plant to be approximately 60 percent and require only limited quantities of cooling water. In addition it may be possible to entirely eliminate cooling water by using air cooling.

The major plant products from this hypothetical plant consist of gas, oil, and power. Each of these can be transmitted long distances in pipelines. Gas and oil pipelines are here today and in the emerging technology of tomorrow I see large blocks of power being transmitted great distances if we refine our knowledge of superconductivity. A plant, such as this, with typical Montana coal deposits, such as Colstrip or Rosebud, could export crude to the mid-West, pipeline gas to the upper and lower Great Lakes, and power to the Northwest. Construction of plants of this size would create satellite industries for the manufacture of plastics, petrochemicals, and refined petroleum products. The availability of cheap power would attract appropriate electrochemical type industries. In many cases, wastes from the coal plant could be used as a source of aluminum and lead to creation of an aluminum industry at or adjacent to the mining-manufacturing complex that I envision.

Plants of this sort will create a number of jobs in mining,

manufacturing, and refining. One such plant built over a period of years could create as many as 15,000 new jobs. Equally important, Montana resources would be used to serve the United States and would contribute to development of the Northern Great Plains. To achieve this worthwhile objective, I feel that OCR should be allowed to continue those of our developments that are already underway and we should be provided with funds to develop direct coal hydrogenation and MHD type power plants. From these developments our plant of the future will emerge producing gas, oil, and power to meet the needs of our people at low cost within our current state of knowledge and technology.


COAL UTILIZATION PLANT
INDUSTRIAL AREA
LIQUID
POWER
GAS
MINERALS
CARBON
UTILIZATION DIVISION
N.P. Cochran Jan. 1969
US DEPARTMENT OF THE INTERIOR


GAS
OIL
POWER
PROJECT
PIPELINE GAS
SYNTHETIC CRUDE
MOTOR FUEL
DIESEL FUEL
JET FUEL
PETROCHEMICALS
POWER
REFINERY
H-OIL PLANT
H-COAL PLANT
COAL MINE
GAS PLANT
COED PLANT
POWER PLANT
LIQUID
HYDROGEN
CHAR
COAL
CO_2
POWER
STEAM
CHAR
WATER
AIR
(OXYGEN)
PROCESS LINES
POWER LINES
FUTURE PROCESS
Cochran OCR - October 1969

FILLING THE GAP WITH COAL

David J. Kull

Like many other persons in this room, I represent a company which expects to benefit from coal research. Let me identify the company, describe its pressing problem and relate both to coal research and development.

Farmers Union Central Exchange is an agricultural cooperative corporation. It functions as a regional supplier serving locally owned cooperatives. They are in the 10-state area from the Great Lakes to the Pacific. The single greatest activity of this company is to supply petroleum products to some 350,000 farm families. That service requires appreciable amounts of crude oil. The present throughput at its Laurel, Montana refinery is 22,000 barrels of crude oil per day. Central Exchange owns and controls approximately one-half of that petroleum throughput. The remaining one-half must be purchased. Projections of future demands indicate a need for constantly increasing volumes of crude oil. In view of the large gap between company-controlled crude oil and ever increasing demands, my company finds cause for concern about future supplies of crude oil for its refinery. The Central Exchange has conducted an ambitious and costly exploration drilling program in the last several years. Though it has discovered a few new oil fields, Central Exchange hasn't succeeded in increasing its proved oil reserves at a rate appreciably greater than its production. Unfortunately, much of the area that has supplied the oil production up to the present time is being rapidly depleted of its oil reserves. Therein lies our problem. The declining amounts of petroleum reserves in the U.S. in general, and the Rocky Mountain area in particular, pose a major threat to the continued successful operation of our Laurel refinery in the 10 to 15 year period ahead. We are continuing our conquest of new oil reserves and are looking closely at remedies. We are trying to recover additional oil from known deposits and to purchase oil reserves from others. But perhaps more importantly in long-term considerations, we are looking at new avenues of approach to our problem. We are considering supplemental supply sources for refinery feedstock: a foreign source: Canada, and a domestic source: coal.

What about Canadian crude to fill the supply-demand gap? Canada is producing oil below its potential. Alberta has a spare capacity near 100,000 barrels daily and that potential could be expanded. But imports to the U.S. from Canada are limited by agreement between the two governments. Historically, we haven't been an importer of Canadian oil This year necessity has forced us to join many others in seeking to supplement dwindling domestic supply with oil from Canada. With some Canadian oil we can postpone cutting refinery runs in the short term. Without Canadian oil, our supply situation is desperate; reduced refinery throughout is inevitable; product supply will be short; and our farmer-patrons' economic plight will be worsened.

We don't want to be too dependent on Canadian oil or purchased

David J. Kull, Manager, Exploration & Production, Farmers Union Central Exchange, Inc., Billings, Montana.

oil. We are also looking to coal to supplement our reserves of liquid fuels. Coal may well be the long-term source of low cost petroleum products we can depend upon. There is no question about the adequacy of coal supply for additional needs. We are hopeful that it will be shown soon that the process for obtaining oil from coal is both technically and economically feasible. So we are trying to keep ourselves informed on the extensive coal-to-gasoline research, looking to the time when we may have to get hydrocarbon fuels from solids.

Central Exchange is not idle as interest widens in the economic potential for producing synthetic fuel from coal. We have actively explored for large reserves of suitable coal to lease. The goal is to strengthen the basic energy raw material position of our company. We recognize a great potential for a synthetic fuel plant in this region at some point in the future. Our organization will continue its interest in commercial exploitation of OCR liquefaction processes. We anticipate that technological successes will lead to increased consumption and continued growth of the coal and coal-related industries in this Western coal area. We are hopeful to be in on the early activity and the benefits therefrom.

The incentive to find a supplement for petroleum is here. To date the coal research has been funded mainly by our Federal Government and a few larger corporations. However, Central Exchange believes that coal need not shape up only as a big company proposition. There should be an important role for joint ventures. Through participation with other refining companies who have similar problems, with utilities who need to supply growing power requirements, and with interested government agencies, we may soon have a good opportunity to help ourselves, our industries and our customers. When the processes are ready and the economics are feasible, Central Exchange will be ready to use coal derived oil for refinery feedstock.

COAL GASIFICATION

Frank C. Schora

INTRODUCTION

Coal-to-gas conversion processes have been under development in the U.S. for several years. Work is proceedings under both government and private sponsorship. There are two basic approaches for the conversion of coal to high Btu pipeline gas (900 + Btu/ft^3):

1. The indirect approach in which a synthesis gas is first formed by the partial combustion of coal with oxygen and/or by the reaction of coal with steam after which the bas is cleaned and catalytically methanated to produce a high methane content gas.

2. The direct approach whcih involves the direct reaction of hydrogen with coal to form methane.

Essentially all processes now under development can be considered as a combination of these two approaches; however, the degree to which each approach is applied in the various processes varies considerably. The basic differences in the processes arises from the manner in which the heat is supplied to support the gasification and hydrogasification reactions.

PROCESS COMPARISON

Process	Heat Source
BCR Super Pressure Bureau of Mines	oxygen
Consolidation Coal CO_2 Acceptor	hot acceptor
Kellogg Molten Salt	molten salt
IGT HYGAS	electrical (hot steam-syn gas) (hot steam - hydrogen)

Of the above processes, only two are now entering the pilot plant stage. Consolidation Coal's CO_2 Acceptor process will be piloted in Rapid City, South Dakota in a plant having a capacity of one ton/hr lignite. Reports are that this plant will be mechanically complete in about 18 months. The Institute of Gas Technology's HYGAS process will be piloted in Chicago, Illinois, in a plant having a capacity of 3 ton/hr of either bituminous, sub-bituminous, or lignite type coals. This plant, which will produce 1 to 1-1/2 million cu ft of high Btu gas per day, will be mechanically complete and ready for initial operation in about 7 months.

Frank C. Schora, Institute of Gas Technology, Chicago, Illinois.

INSTITUTE OF GAS TECHNOLOGY HYGAS PROCESS

The IGT HYGAS process is based on the high-pressure, high-temperature reaction of coal with a hydrogen-steam mixture at pressures of 1000 to 1500 psi. In this process, heat generated by the hydrogen-coal reaction is utilized in supporting the steam-carbon reaction to produce additional hydrogen and carbon monoxide. The gas mixture after cleaning is passed over a catalyst where the CO and hydrogen are reacted to form methane, thus producing a high methane content product having a heating value of 950 + Btu. Char resulting from the hydrogasification reaction is further reacted with steam in an electrothermal reactor using electric power as the heat source. In this reactor hot hydrogen necessary for the hydrogasification reaction is produced at system pressure. Spent char from this reactor is used as fuel to generate the steam and electric power required in the operation. In normal operation there is no byproduct char.

The development of the IGT HYGAS process is being carried out under joint sponsorship of the United States Department of the Interior, Office of Coal Research, and the American Gas Association. The program has been jointly funded by these organizations since 1964, prior to which it was solely supported by the American Gas Association.

In the pilot plant we plan to test both Eastern and Western coals. We believe that by 1972 we will have developed sufficient information to verify economic estimates and to complete the design of a commercial sized demonstration plant.

One of the major reasons for locating the pilot plant in the Chicago area was to facilitate the delivery of coals from all parts of the country, both East and West. In designing the plant we have taken into account the characteristics of Western coals so that they can be evaluated in the plant.

We have conducted test work in our pilot unit reactor with both Eastern and Western coals. We have worked with a total of eleven coals, four of which are from the West:

North Dakota lignite
Montana lignite
Montana subbituminous
Colorado subbituminous

We have found that the Western coals tend to be more reactive than the Eastern bituminous coals, which generally require pre-treatment to overcome agglomeration problems in the reactor system.

An extensive economic analysis based on Dakota lignites was undertaken for the HYGAS process and has been published by the United States Department of the Interior, Office of Coal Research. This study was based on the production of 500 billion Btu's per day of pipeline gas, which is equivalent to 523 million cu ft of gas having a 954 Btu per cu ft heat content. It is based on the projected use of an MHD power plant to generate the necessary electrical power because such a system requires a minimum amount

of cooling water. Such a plant will require 18.4 million tons of 7345 Btu per pound lignite yearly. Table 1 shows the investment for such a facility, and Table 2 shows a breakdown for operating costs.

GAS SUPPLY

On October 22, 1969 the third report by the Future Requirements Committee, which is administered by the Denver Research Institute and conducted under the auspices of the American Gas Association, the American Petroleum Institute, and the Independent Natural Gas Association of America, indicated that the annual U.S. gas requirements will increase from 21.5 trillion cu ft in 1968 to 46.7 trillion cu ft in 1990. Assuming that a reserve to production ratio of 10 years is needed to maintain adequate deliverability, then an average of 43 trillion cu ft/yr must be discovered each year over the next 22 years. Since 1953, gross additions have averaged less than 19 trillion cu ft/yr and have never exceeded 25 trillion cu ft annually. If it is assumed that net imports of natural gas will rise from the present level of 3% of domestic demand to 10% by 1990, the remaining deficiency of gas, based on optimistic estimates of new U.S. supplies and imports, will be between 300-400 trillion cu ft and will grow at an annual increment of 1.5 trillion cu ft/yr. Other than a drastic increase in exploration or a breakthrough in new exploration techniques, the only way to overcome this deficiency is by production of synthetic pipeline gas from coal or lignite. To meet this demand, nine 500 million cu ft/day HYGAS plants will be required to be put into operation each year.

In order to minimize the time to commercialization, the American Gas Association has just authorized a preliminary design study for a commercial sized demonstration plant. This plant will be of the order of 100 million cu ft/day capacity and will be expandable to 250 million cu ft/day. By undertaking this study now, with the assistance of Procon Incorporated, who are engineering and building the pilot plant, we believe we can shorten the time to commercialization. If the HYGAS process can be proven at the pilot plant level by 1972, we believe it is possible to have this commercial sized demonstration plant ready for commissioning by 1974.

Table 1. INVESTMENT SUMMARY
(500 billion Btu/day pipeline gas from lignite, 90% plant operating factor, MHD steam cycle with producer gas feed)

Section	Equipment, $	Bare Cost, Installed, $
Lignite Storage and Reclaiming	1,710,000	3,420,000
Lignite Grinding and Drying	5,864,000	11,728,000
Slurry Preparation	1,652,700	4,958,000
Hydrogasification, Electrogasifier, Quench and Light Oil Separator	35,681,700	68,887,000
Prepurification I	4,767,200[1]	8,340,000
CO Shift	1,913,500[2]	3,587,000
Prepurification II	4,130,000[3]	7,888,000
Methanation, Drying	4,117,500[4]	6,706,000
Offsite Equipment (including $76,820,000 for MHD and associated equipment)	--	86,144,000
Subtotal, Bare Cost		201,658,000
Contractor's Overhead and Profit		15,588,000
Subtotal		217,246,000
Interest During Construction, 5% of Subtotal		10,862,000
Total Fixed Investment		228,108,000
Working Capital		
Raw Material	1,989,000	
Other Direct Materials	93,000	
Accounts Receivable	5,003,000	7,085,000
Total Capital Investment		235,193,000

[1] Includes $121,500 tower packing.

[2] Includes $240,000 initial catalyst charge.

[3] Includes $372,000 tower packing plus initial zinc oxide and carbon.

[4] Includes $1,811,000 initial catalyst charge.

Table 2. OPERATING EXPENSE AND REVENUE REQUIREMENT
(500 billion Btu/day pipeline gas from
lignite 90% plant operating factor)

	¢/10^6 Btu
Lignite at 8¢/10^6 Btu	13.1
Other Direct Materials	0.6
Labor and Maintenance	8.0
Capital Charges	11.1
Contingencies	0.7
Total Operating Expense	33.5
Byproduct Credits*	7.88
Net Operating Expense	25.7
Gross Return (7% of rate base)	4.9
Federal Income Tax (48%)	2.3
20-year Average Gas Price	32.9

* Includes power at 0.3¢/kWhr, oil at 25¢/10^6 Btu, benzene at 15¢ gal.

PROSPECTS FOR COAL LIQUEFACTION

C. G. Herrington

We in Humble are most appreciative of the invitation to participate in this panel discussion. It is a pleasure to be a part of this program concerning new and promising uses for Montana's vast coal deposits. These deposits are impressive in size, even in Texas, where the East Texas oil field with its over five billion barrels of reserves has, through the years, made a valuable contribution toward meeting the nation's energy requirements. It is not difficult to understand why we are impressed when one considers that the latent energy contained in Montana's coal fields is equivalent to that produced from more than 100 such oil fields. Such a tremendous potential here and in other coal producing states cannot be ignored in approaching the problems of supplying the growing energy requirements in the United States. The technical opportunity for converting this resource into useful liquid and gaseous fuels has encouraged my company to acquire coal reserves and to pursue a research program related to coal.

I would like to show you by means of slides how we look at the nation's energy requirements and supply sources during the quarter century between 1960 and 1985. For the text of the proceedings of this conference, I'll briefly describe the highlights of each slide. (See end of this paper for copies of the slides.)

This slide shows that total requirements this year amount to about 70 quadrillion BTU's, up from 50 quadrillion in 1960. Our forecast is for a continued increase in requirements to a level approaching 120 quadrillion in 1985. Presently, about 3/4ths of the total is supplied by oil and gas and most of the remainder by coal. The look ahead to 1985 indicates that oil and gas will drop to about 2/3rds. You will note that coal, beginning in the early 70's, is expected to broaden its contribution and reach a level in 1985 that is more than 60 percent above its present volume, even though its percentage contribution remains about constant at 22 percent.

We will turn now to the second slide, which shows the petroleum liquids supply and demand picture expressed in millions of barrels per day. Current requirements are about 12 million as compared with 9 million in 1960 and an anticipated 20 million or more in 1985. The striking feature is that crude oil production from currently booked reserves is forecast to decline drastically from 8 to about 3 million barrels per day. We believe that imports will be permitted to grow, but for national security and other reasons should not be allowed to dominate the picture. This means that crude oil production from reserves that are not yet booked will play an increasing role in supplying demand. According to this outlook, such production will fill about 1/2 of the requirements in the terminal year.

It is within this expanding wedge that Arctic oil as well as undiscovered deposits in other areas will be needed to meet demand. It is within this area, also, that synthetics will find

Carl B. Herrington, Vice President and Director, Humble Oil and Refining Company, Houston, Texas.

a place. As technology is perfected to make synthetics competitive, the vast reserves of coal, oil shale and tar sands could be booked on equal terms with petroleum as sources of liquid fuel for the future. When we look at the shape of this wedge and think in terms of projections to the end of this century and beyond, the question is not one of whether such minerals can be so classified but when will it be economically feasible to do so.

The factors which can be expected to influence the emergence of coal as a raw material for the production of liquid fuels can be reduced to two broad categories: the first, competition from alternatives; and the second, the rate of technological development.

Synthetics must, of course, compete with conventional petroleum supplies coming from increased domestic production and with imports. When we consider the prospects of increased domestic production, we must admit that it is difficult and perhaps impossible to predict future discoveries of crude oil with a high degree of accuracy. While many forecasts have been made, essentially all of them suggest that during the 1970's, U.S. reserve additions may not keep pace with requirements.

Imports are now the subject of a national debate, the outcome of which promises to have far-reaching consequences for the nation. This is a matter that involves national security and, therefore, must be approached in a guarded manner. You may be interested in our analysis of the petroleum supply outlook in the absence of import controls. As shown on this next slide, imports would expand rapidly to take over the markets now supplied by domestic production. Production from booked reserves would virtually disappear by 1985, and production from future reserves would become, with time, of less importance. In such an environment. it is doubtful that synthetics from any source would have a place. We sincerely hope that, at the end of the current debate, the nation will have an imports policy which will provide a sound basis for healthy growth of domestic energy supplies, whether they be conventional petroleum or synthetics.

Future developments toward commercialization of the widely publicized Athabasca tar sands and the oil shale deposits of Colorado, Utah and Wyoming could have an important bearing on the timing of a viable coal conversion industry. The Great Canadian oil sands plant is presently the only commercial synthetics venture in operation on this continent; and, as such, it is being observed with intense interest. In this country, oil shale deposits have received attention as a source of potential liquid fuels for over 40 years, and the technology for converting oil shale into synthetic fuels is probably well ahead of coal conversion technology.

Both tar sands and oil shale possess certain advantages and disadvantages relative to coal. On the plus side, the raw liquid appears to be much more amenable to upgrading into a synthetic crude oil which could be processed by conventional refining techniques. Tending to offset this advantage is the large amount of waste solids, amounting to some 85 or 90 percent for both oil shale and tar sands, which must be discarded at some expense after the organic matter has been separated from it. For coal, the waste material is essentially the ash content, which normally amounts to some 5 to 15 percent.

Now, in turning our attention to the technological aspects of converting coal to useful liquids, it will be helpful to remember that for a long time it has been technically possible to make gasoline from coal. To our knowledge, however, no means exist today for accomplishing this conversion at a cost low enough to displace other fuels from the market. We anticipate that this situation will change through the combination of technological breakthroughs and changing economics as the finding and developing of conventional sources of petroleum to meet the increasing demand become more difficult.

Humble, through its research affiliate, Esso Research and Engineering Company, has operated a pilot plant for the past 2½ years. The purpose of this operation has been to gather data concerning the various process conditions necessary for the conversion of coal to gasoline. Although frustrating at times, the work has not been without success. We have been able to liquefy coal on a continuous basis. We have also gained a better definition of the nature and scope of the many problems which must be solved before coal liquids become a commercial reality. Hopefully, we have gained knowledge which will be helpful in the overall solution to at least some of these problems.

As you can visualize from looking at a lump of coal, there are many complicated steps involved in its liquefaction. Under heat and pressure and sometimes in the presence of special catalysts, chemical bonds are broken and hydrogen is introduced into the resulting fragments. Generally, soft coals contain about 5 percent by weight of hydrogen already chemically bonded. In the hydrogenation process, it is necessary to double this amount of hydrogen. Hydrogen is a very expensive element to isolate in commercial quantities and is thus a significant cost factor in synthesis. Today, the common practice in the petroleum and chemical industries is to derive their hydrogen using natural gas as the raw material; but the current forecast of limited supplies of natural gas has generated a need for a research effort directed at the production of low-cost hydrogen from solid fuels such as coal or char, a by-product of the liquefaction process.

Concurrently with the research effort at our Baytown, Texas, laboratories, we have supported engineering and economic studies of the prospective processes for commercial operations. The result of this work has helped to orient us as to where we now stand with respect to achieving our objective of developing a competitive coal-to-gasoline process. From what we know today, we can say that substantial breakthroughs are necessary to make coal liquids competitive in the present economic environment. Other firms are carrying out research in the same field, much of which is being funded by the Department of the Interior through the Office of Coal Research. As far as we know, the status of this work is much the same as ours; that is, progress has been made, but the targets are yet to be achieved. Our work is proceeding, and we are hopeful that the final results will be of service to the nation and profitable to us.

Many studies have been published outlining the probably nature of commercial coal liquefaction facilities; and, in the interest of time, I will not go into any great detail on this subject. I might mention that we expect these plants to be large and to require an immense amount of capital. For example, a plant to produce 100,000 barrels of synthetic crude oil daily might require

on the order of 20 to 25 million tons of coal each year. Mining investment for this volume would approach $50 million, and conversion facilities would cost in the league of $350 million. Remember, I am speaking here of only a single plant; and, at such time as coal becomes an economic raw material for liquid fuels, a number of such plants may be needed in Montana.

The facilities for coal conversion will be highly capital intensive; but, even so, much skilled manpower will be required for their construction as well as operation. You can also appreciate the impact of such operations on the mining industry -- increased use of mining talent, development of new types of mining equipment, stepped-up research and the development of new technology. It will mean new opportunities for many people for one of the major challenges will be in recruiting and training the necessary manpower. Large numbers of technical, professional and production personnel with high-level skills and imagination will be needed. New housing, recreation and support facilities will be necessary, and it is easy to visualize new communities of a model nature appearing within the state.

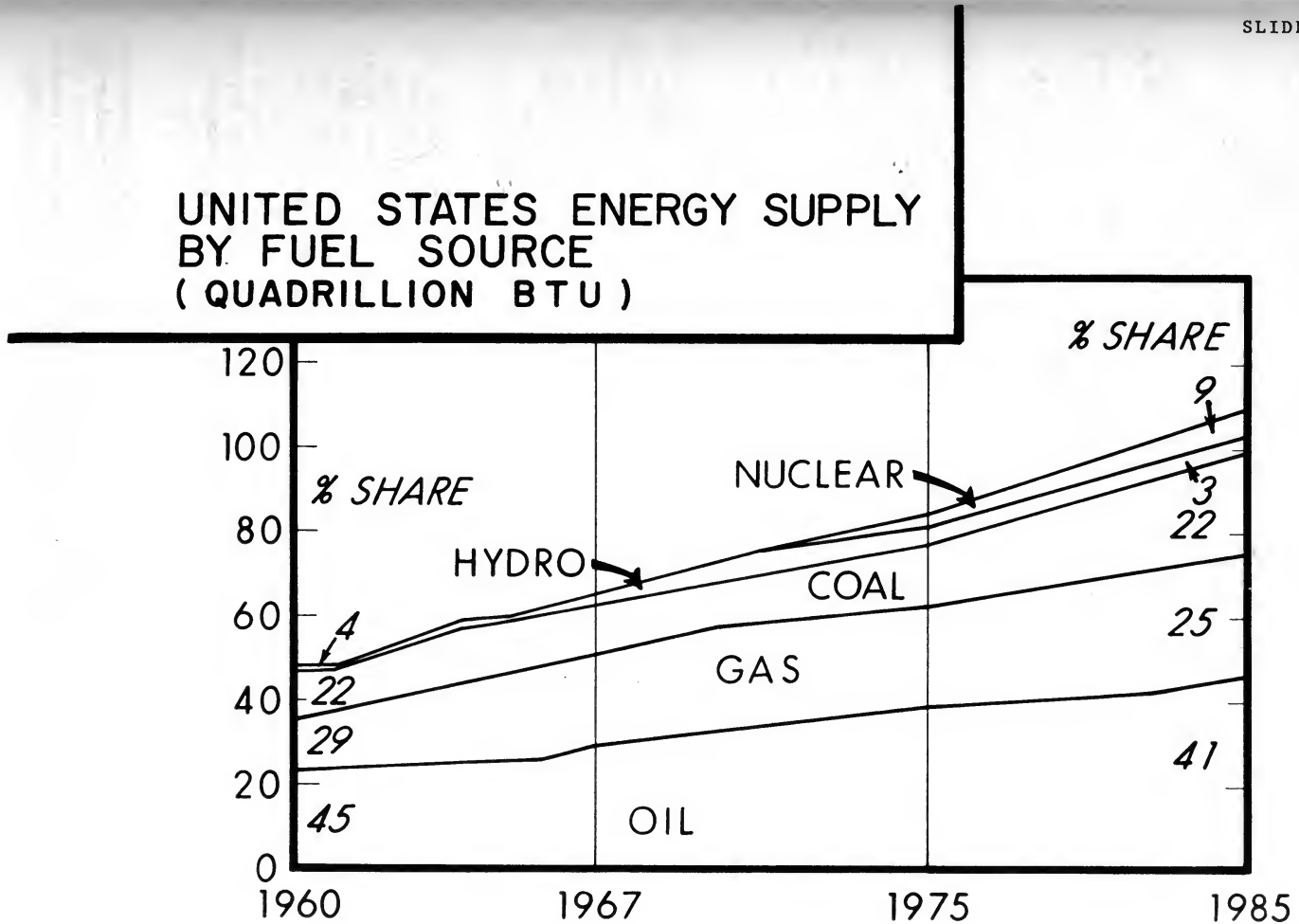
On the subject of near-term commercialization of Montana's coal, we all recognize that geography is the factor which has kept it from competing as fuel for electric power generation in some of our nation's major population centers. As discussed in this symposium, new developments are needed, either in the form of a cheaper means of transportation or a substantial improvement in the efficiency of transporting electricity by wire. The recent arrangement for the shipment of a substantial amount of Montana coal to a power plant in Minnesota may be a breakthrough. Certain characteristics of much of the coal in Montana -- it has low sulfur content and is available with low-cost surface mining techniques -- make it desirable, and we may expect much more intensive study in the future of means for overcoming the transportation problem.

There are, of course, those who look upon large-scale commercialization as a mixed blessing, having in mind the possible adverse effects of industrialization of the area on air and water quality. Such concern may have been well founded a decade or two ago, but we believe that plans for large installations of the future will recognize the need to protect the environment in which they are located. We base this opinion on the fact that advanced technology is now available and that industry is aware of its responsibilities relative to atmospheric and water pollution. Although we cannot predict just when a coal conversion industry will emerge in the west, it is safe to say that when it does, it will provide its benefits without unduly affecting the desirable features of the area which most westerners are anxious to protect.

As we all know, energy requirements may be equated with the rate of progress. We can look forward to continually increasing demands for energy; and, although there are many problems and challenges involved in supplying the needs, those areas with low-cost energy supplies will surely participate in future growth. We believe that there is a real future for Montana coal and, indeed, for the entire state of Montana, as our operations in the state will attest. As the largely untouched potential of Montana coal is tapped, we believe that the benefits to the state will be substantial.

In summary, coal can be liquefied but not on an economically competitive basis today. When it will be economical depends upon such factors as the technological developments, outcome of the oil import control program review and success of future oil exploration efforts.

(The following three pages give copies of the slides used during this talk.)


UNITED STATES ENERGY SUPPLY
BY FUEL SOURCE
(QUADRILLION BTU)
% SHARE
% SHARE
120
100
80
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NUCLEAR
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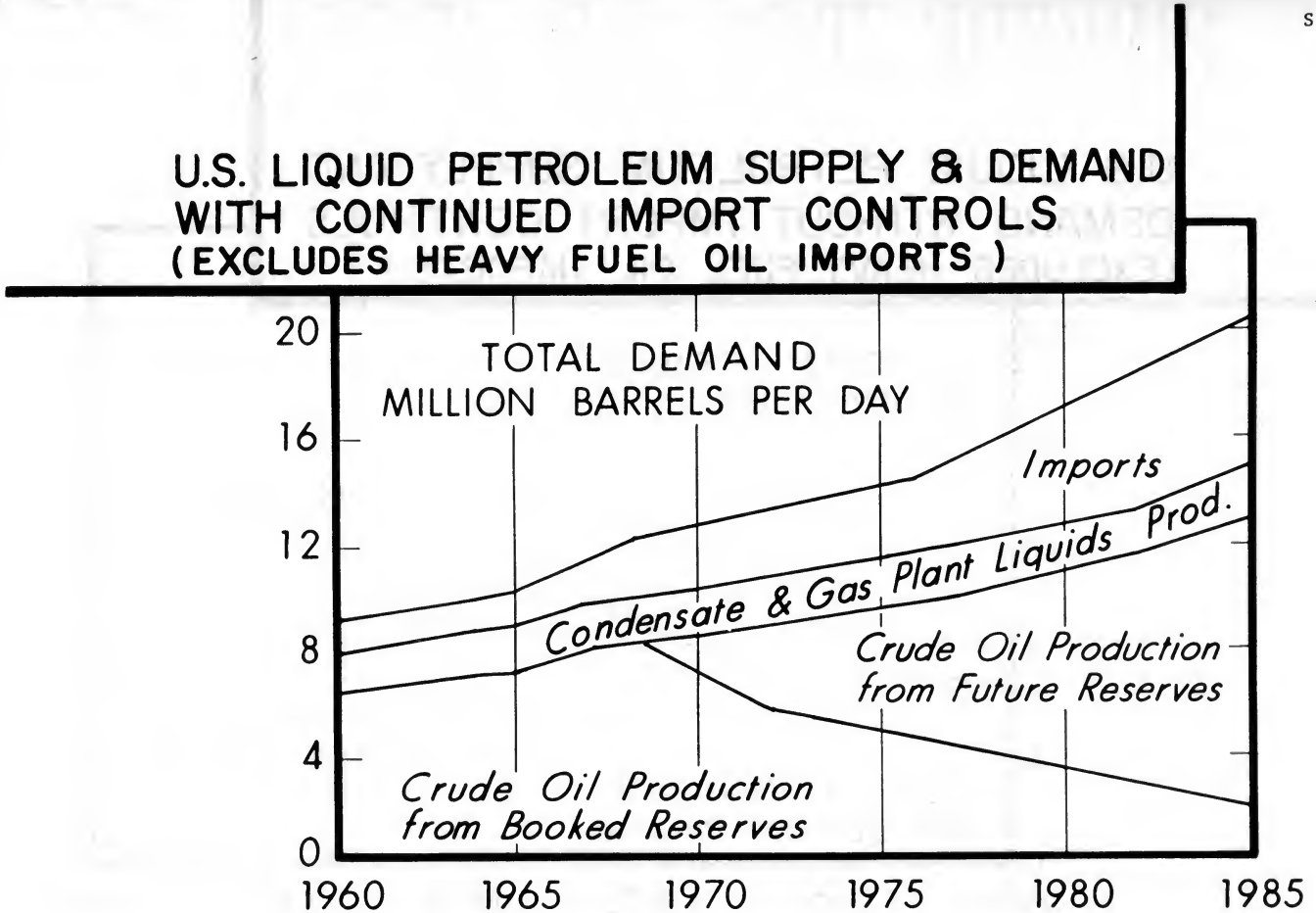
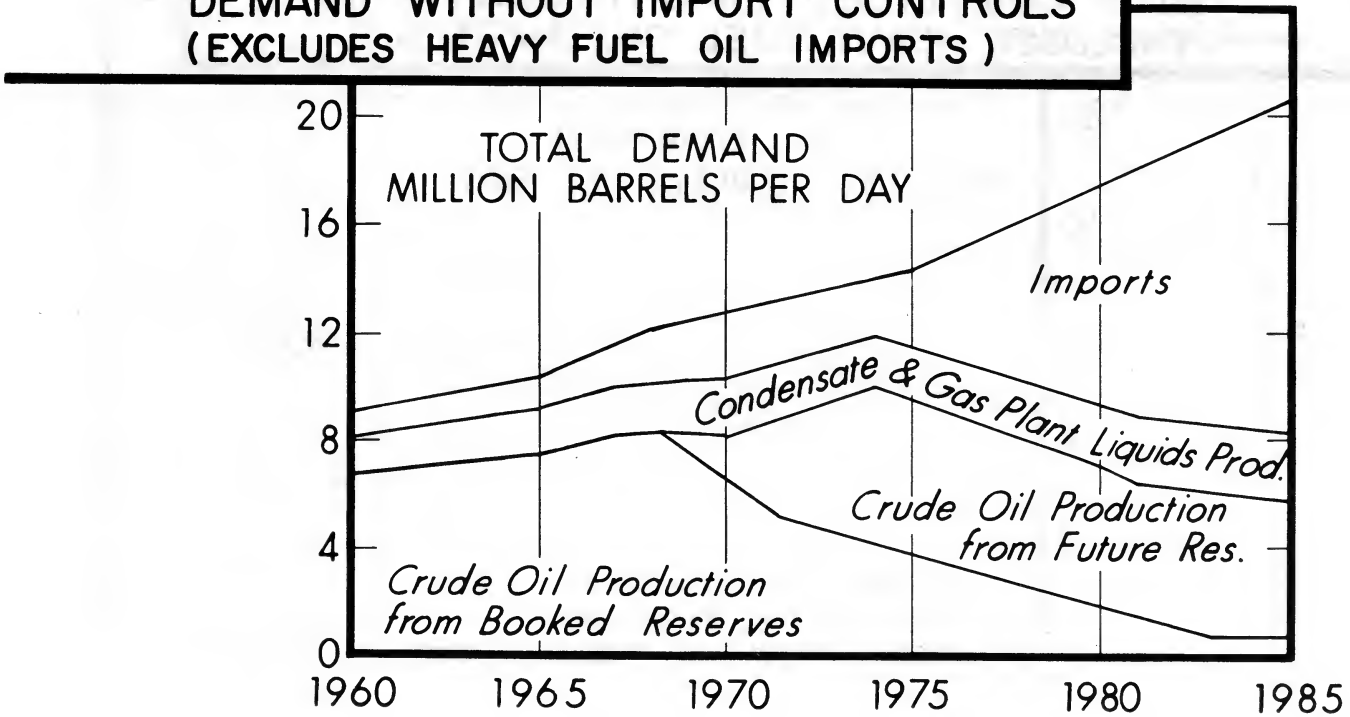

U.S. LIQUID PETROLEUM SUPPLY & DEMAND
WITH CONTINUED IMPORT CONTROLS
(EXCLUDES HEAVY FUEL OIL IMPORTS)
TOTAL DEMAND
MILLION BARRELS PER DAY
Imports
Condensate & Gas Plant Liquids Prod.
Crude Oil Production from Future Reserves
Crude Oil Production from Booked Reserves
20
16
12
8
4
0
1960
1965
1970
1975
1980
1985

U.S. LIQUID PETROLEUM SUPPLY AND DEMAND WITHOUT IMPORT CONTROLS
(EXCLUDES HEAVY FUEL OIL IMPORTS)



CONVERT COAL TO LIQUID FUELS WITH H-COAL

Clarence A Johnson

"The domestic oil industry cannot afford to be complacent because of the discovery of significant new oil reserves in Alaska." So stated Michael L. Haider, Chairman of the American Petroleum Institute on October 14 at the Texas Mid-Continent Oil and Gas Association Meeting in Houston. It has been estimated that the Alaskan oil reserves are in the range of 10-30 billion barrels, or 2-6 years' supply for the United States at the present level of consumption. Mr. Haider predicted that the North slope operations would delay the commercial production of synthetic oils five to ten years. In 1967 it was predicted that commercial synthetic fuels would be required by 1975 so that presently the date for commercialization is 1980 to 1985. However, unless the research effort on coal liquefaction processes is increased it may not be possible to meet this new schedule.

The coal deposits in the United States potentially represent an oil reserve many, many times the most optimistic crude oil reserve estimate. For example, it is estimated that the coal reserves in the Crow Indian reservation holds 30-billion tons of coal. The H-Coal process can produce 100 billion barrels of oil from this single coal reserve, representing 20 years' supply for the United States. The available coal reserves of the United States could supply over 2,000-billion barrels of crude oil.

Development of the H-Coal Process was initiated by HRI in 1963, but major expansion of effort was started in February, 1965 when the Office of Coal Research (OCR) awarded a $2-million, three-year contract to HRI to continue development. The program was outstandingly successful, and we predict that the H-Coal Process will have profitable applicability to the processing of bituminous and subbituminous coal and lignite.

Development work was conducted in bench-scale and process development pilot plants; the latter handling three tons of coal per day. Progress was sufficiently rapid that after eighteen months of effort, the OCR invited HRI to submit a proposal for the next stage of development. It was decided that this should be a 250-ton-per-day pilot plant and a proposal for this program was submitted to the OCR in September, 1966. This pilot plant would preferably be located at a mine site. Montana would be a logical site for a pilot plant. This is a much larger pilot plant than any of the other OCR-sponsored coal liquefaction processes, but it is essential to carry out experiments on this scale before a commercial plant is built.

Economic evaluations of the H-Coal Process, performed by HRI in 1966, indicated that gasoline could be produced from coal for 12-13 cents per gallon. An independent evaluation made in 1968 by the American Oil Company, under contract to the Office of Coal Research, confirmed the technical feasibility of the H-Coal process and, on a comparable basis, substantially checked HRI's economics. The American Oil Company also recommended that the

Dr. Clarence A. Johnson, Vice President -- Research, Hydrocarbon Research, Inc., Trenton, New Jersey.

next stage of development should be a pilot plant of 250-500-ton-per-day capacity.

Basically, the H-Coal Process involves the hydrogenation of pulverized coal at elevated temperatures and pressures in the prescence of a catalyst. The outstanding feature of this process is a novel reactor system employing a unique means called the "ebullated reactor technique" to accomplish the efficient contacting of hydrogen with solid coal and catalyst dispersed in a self-produced liquid oil. During the reaction enormous quantities of heat are generated, but the ebullated bed technique permits absolute and uniform control of the temperature as well as recovery of this heat for process steam and power requirements. The H-Coal process produces a synthetic crude oil which is then refined by commercially-available techniques to finished products.

During HRI's OCR program, it was not possible to test any Montana coal. However, a bench-scale evaluation was carried out on a Wyoming subbituminous "C" coal (Wyodak mine) which is somewhat similar to your Coalstrip subbituminous coal.

A comparison of the coal analysis is shown in Table 1. On the basis of our experience on other, similar coals, the Montana Coal strip coal should yield higher liquid yields in the H-Coal system than the Wyodak coal. (Tables and Figures at end of paper.)

The yields obtained from Wyoming subbituminous coal are shown in Table 2. Yields and conversions are given on the basis of moisture- and ash-free coal since ash contained in the coal is inert, unconvertible material, and passes through the reactor. It should be noted that the coal conversion is low and may have been caused by oxidation prior to testing. It is believed that the conversion should be about 90%, comparable to that obtained with Illinois No. 6 as well as many other coals.

Liquid product inspections of the crude H-Coal product are shown in Table 3. This is a high-quality crude which can be refined by conventional processes. The gasoline, after reforming, is highly aromatic and can meet premium-grade octane values without tetraethyl lead addition. Lead-free gasoline has been recommended for use in certain areas as a means of reducing air pollution caused by automobile exhaust.

Figure 1 shows a pictorial flow diagram of an overall coal refinery utilizing the H-Coal process. The major products from this coal refinery are gasoline and No. 2 fuel oil. The respective amounts of these two products can be changed to the extent of producing all gasoline. Small amounts of No. 6 fuel oil and char constitute the remaining products. The char is consumed as fuel for hydrogen production. Hydrogen sulfide and ammonium sulfide are recovered and converted either to sulfur and ammonia or to sulfuric acid and ammonium sulfate, depending on market requirements.

An economic summary of a 100,000 BPSD H-Coal refinery is presented in Table 4. It is assumed that the refinery is a grass-roots plant built in the vicinity of the coal source.

All on-site and off-site facilities are provided to make the plant complete within itself when located in a remote area. Run-of-mine coal, high voltage electricity, and either river or well

water are assumed available to the plant. These economics assume successful development of the coal and char-fired reformer for hydrogen production. The investment includes the complete refinery, the hydrogen plant, all off-sites, and facilities to recover and purify sulfur, anhydrous ammonia, LPG, and benzene.

Case 1 for each location is based on a nominal capacity of 100,000 barrels per day of gasoline. Case 2 includes recovery of available liquefied petroleum gas (LPG) and 3,000 barrels per day of benzene. Air cooling is maximized for the western location since there is a scarcity of water.

In September 1967, HRI's OCR contract was terminated for the convenience of the government due to lack of funds. Since that time development of the H-Coal process has been continued on a limited basis with in-house funds and support from the Atlantic Richfield Company. Progress has been excellent and at this time I wish to mention two significant areas of progress.

The coal throughput has been increased from 30 pounds of coal per cubic foot of reactor per hour and used for the economic analysis which I presented earlier to 300 pounds of coal per cubic foot of reactor. The pressure has been reduced from 3,000 (again in the pressure employed in our economic evaluation) pounds per square inch to 750 pounds per square inch.

Now let me explain the significance of these developments. At a coal throughput of 30 pounds per hour per cubic foot of reactor, some twelve of the largest reactors that can be built would be required for a 100,000 B/D plant. At 300 pounds per hour per cubic foot, only two such reactors would be required.

Operating pressures of 3,000 pounds per square inch are employed in many commercial plants today, but the equipment, such as reactors, pumps, heat exchangers, and valves, is heavy and expensive. A reduction from 3,000 to 750 pounds per square inch can reduce significantly the capital and operating costs. Based on some very preliminary data and certain assumptions, we have estimated that gasoline can be produced for 10-11 cents per gallon employing these new innovations. The hydrogen requirements can be drastically reduced at high coal rates, but with a corresponding increase in the yield of residual fuel oil. This heavy fuel oil has significantly less sulfur than the original coal, and in some areas will satisfy the sulfur restrictions imposed on power plant fuel.

A schedule for design, construction, and operation of the 250 T/D pilot plant is shown in Figure 2. The program encompasses design, engineering, equipment procurement, and construction of the pilot plant located near the source of coal, and operation of the constructed pilot plant for eighteen months. The total cost of the program is about $25-million.

The results of the pilot plant program will allow a competent engineering company to design and construct a full-scale commercial plant. However, if the pilot plant design is started in 1971, it is unlikely that a commercial H-Coal refinery will be in operation before 1980. It is essential, therefore, to proceed at this time with the development of the H-Coal process and the pilot plant program if commercial coal liquefaction is to be realized in the 1980's.

In conclusion, the H-Coal process can

(1) Satisfy the need for liquid fuels in the United States, not for two years or six years, but for generations.

(2) Solve the air pollution from automotive exhausts by eliminating the need for tetraethyl lead in the gasoline product.

(3) Produce a heavy fuel oil with significantly less sulfur than the original coal.

TABLE I

COMPARISON OF WYOMING AND MONTANA COALS

	Ultimate Analysis, % By Weight	
	Wyoming Wyodak	Montana Coalstrip
Moisture, As Received	24.0	21.6
Dry Basis		
Carbon	68.9	66.2
Hydrogen	4.3	4.6
Nitrogen	1.0	1.0
Sulfur	0.6	0.8
Ash	8.7	11.4
Oxygen	16.5	16.0
Heating Value (Btu/Lb)	8100	11,600

TABLE 2

YIELDS BASED ON MOISTURE- AND ASH-FREE COAL

WYOMING SUBBITUMINOUS COAL

	Yields % By Weight
Light Gas, C_1-C_3	10.8
Liquid Product	56.1
Unconverted Char	18.6
Hydrogen Sulfide, Water, Ammonia	12.9
Carbon Monoxide, Carbon Dioxide	6.6

Conversion = 81.4% By Weight

TABLE 3

LIQUID PRODUCT INSPECTIONS - WYOMING SUBBITUMINOUS COAL

ASTM Cut Points		% By Volume	Gravity °API	Liquid Yield	
				% By Weight*	Barrels/Ton*
Naphtha,	C_4-400°F	39.4	50	18.5	1.35
Light Distillate,	400-650°F	27.6	21	15.5	0.95
Heavy Distillate,	650-975°F	18.0	4	11.1	0.62
Residuum,	975°F+	15.0	-16	11.0	0.52
Total		100.0		56.1	3.44

* Of Moisture- and Ash-Free Coal

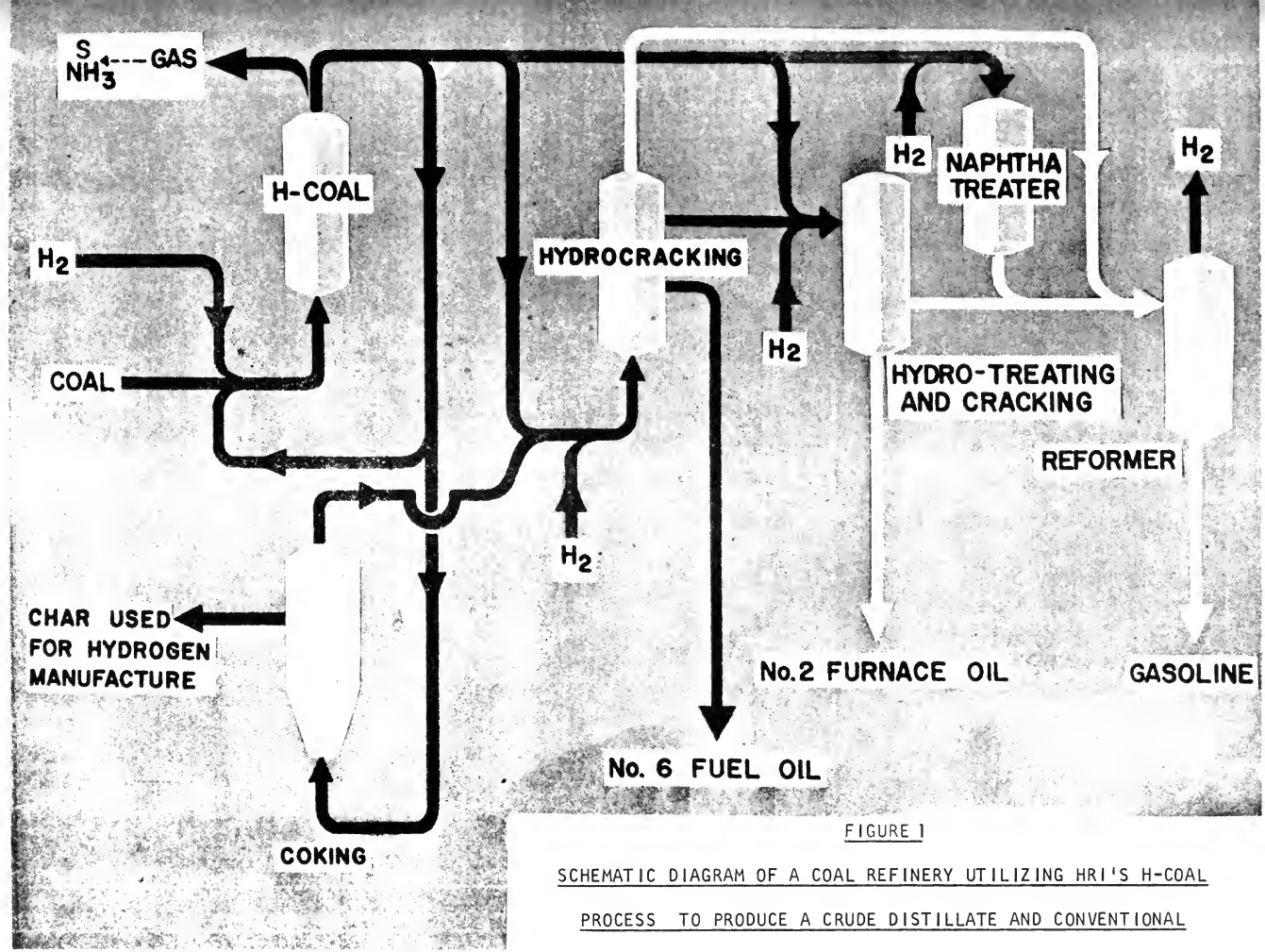


FIGURE 1

SCHEMATIC DIAGRAM OF A COAL REFINERY UTILIZING HRI'S H-COAL PROCESS TO PRODUCE A CRUDE DISTILLATE AND CONVENTIONAL COMMERCIAL PROCESSES TO UPGRADE THE DISTILLATE TO FINISHED PRODUCTS

TABLE 4

ECONOMIC SUMMARY FOR COAL REFINERY - 100,000 BPSD NOMINAL CAPACITY

WESTERN LOCATION - WYOMING SUBBITUMINOUS COAL[1]

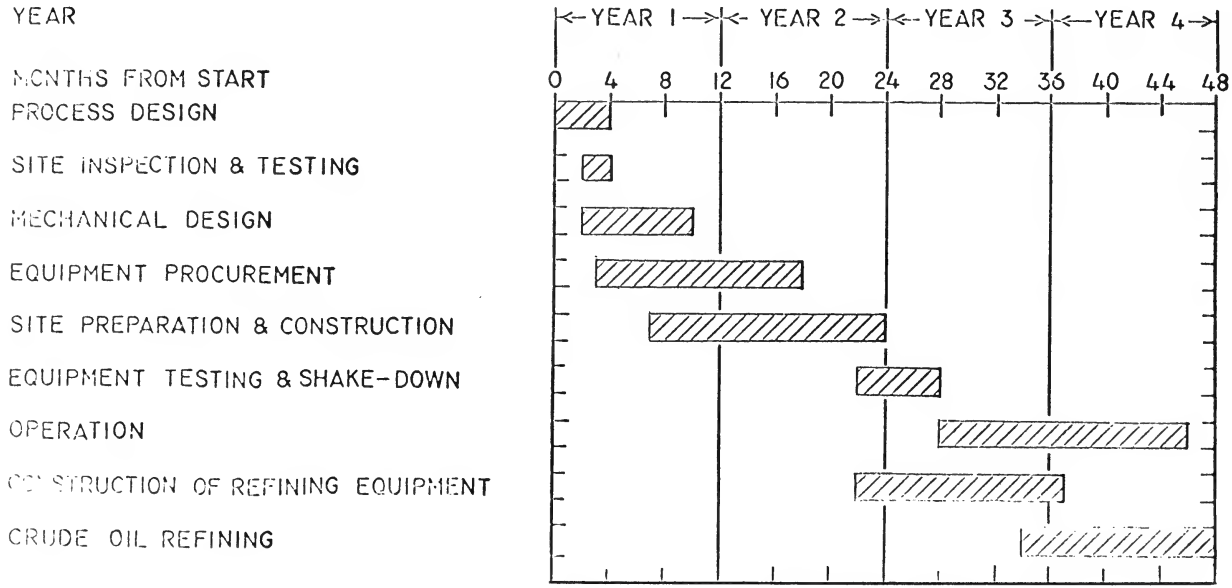
Case		1	2
Plant Investment, M $			
On-Site		336,400	344,200
Off-Site		66,300	72,800
Total		402,700	417,000
Working Capital, M $		37,500	37,500
Annual Revenue, M $	Unit Price		
Gasoline	$0.12/Gal	167,933	162,943
No.6 Fuel Oil	$2/Bbl	1,705	1,705
Sulfur	$25/L.Ton	906	906
Ammonia	$30/S.Ton	2,306	2,306
LPG	$0.055/Gal	-	7,623
Benzene	$0.23/Gal	-	9,563
Total Revenue		172,850	185,046
Annual Cost, M $			
As-Received Coal	$1.20/Ton	22,322	23,442
Electricity	$0.0045/KWH	12,847	13,509
River Water	$0.01/M Gal	35	35
Chemicals & Catalyst		18,652	18,656
Operating Labor	$3.75/Man-Hr	3,318	3,515
Supervision @ 40% Labor		995	1,055
Overhead @ 100% Labor & Supervision		4,313	4,570
Insurance & Taxes @ 2% Total Investment		8,054	8,340
Maintenance			
@ 4% On-Site Investment		13,456	13,768
@ 2% Off-Site Investment		1,326	1,456
Interest on Working Capital		1,875	1,875
Depreciation, 15-Year Straight Line		26,847	27,800
Total Costs		114,040	118,021
Profit Before Taxes, M $		58,810	67,025
Profit After Taxes @ 48%, M $		30,581	34,853
% Return on Investment as Profit		7.6	8.4
Total Cash Flow, M $ [2]		57,428	62,653
Payout Period, Years		7.0	6.7

(1) Excludes Applicable Royalties
(2) After-Tax Profit and Depreciation

FIGURE 2

PROJECTED SCHEDULE

SCHEDULE FOR DESIGN, CONSTRUCTION AND OPERATION OF H-COAL PILOT PLANT AND REFINING FACILITIES



COAL SYMPOSIUM SUMMARY

Perry F. Roys

To attempt to summarize this meeting in which so many experts have appeared makes me feel like the man who had gone through the Johnstown flood and found great pleasure in life in telling others about it. Upon his death and entrance to Heaven, Saint Peter asked him what he would most like to do, and he said that he would like to hold a meeting and tell everyone about the Johnstown flood. Peter said that he would be glad to arrange such a meeting. "But," he added, "I want you to realize one thing: You've got Noah in the audience."

Many Noahs are here, and I am sure that all of us who have attended are indebted to the speakers and to those who arranged the Symposium. Surely, you will agree that this has been a most informative and stimulating two-day session.

It might properly have been called COAL AND POWER Symposium -- for these were the themes that ran through the conference -- beginning with Governor Anderson's opening remarks: The reality of the coal supply; the imminence of the energy demand; the promise of technological development to bring the supply to satisfy the demand. The other theme was one of cooperation and understanding to bring about the profitable utilization of this great coal resource without penalizing citizens in all walks of life by causing harmful effects on the environment we prize so dearly.

The speakers left no doubt as to the abundance of Montana's coal supply. Vice President Phillips of Peabody Coal reminded us that, taken all together, our supply of lignite, bituminous, and sub-bituminous coals give us the greatest reserves of any of the states -- 378 billion tons. Much of this lies in thick beds close to the surface. In his keynote speech David Freeman of the Office of Science and Technology pointed out that the 14 billion tons amenable to strip mining in Montana alone represent as much energy as the entire proven reserves of natural gas in the United States. And this morning Geologist Matson quoted Montana Bureau of Mines estimates of the same resource running as high as 17 billion tons.

On the energy demand side, many of our speakers in many different ways reinforced the picture Mr. Freeman gave us of what he called "Crisis Amid Abundance." They repeated the fact that as a nation, our energy demands have doubled (and will apparently go on doubling) every 10 years or so -- and the panelists yesterday afternoon representing power districts and associations well within potential markets for Montana coal gave testimony to demands for growth well ahead of the national rates. As Mr. Warne put it at the luncheon yesterday, this means that by the year 2000, for every kilowatt generated today we will need SEVEN then.

But Montana's coal is not located where the greatest blocks of additional energy demand are developing; so several of the

Perry F. Roys, Executive Director, Montana Department of Planning and Economic Development, Helena, Montana.

papers presented ways of bridging the space gap. To overcome Montana's remoteness, Ken Holum predicted that studies will almost certainly establish the feasibility of "mine-mouth generation" of power, plus extremely high-voltage transmission from Montana to supply power needs of a major portion of the West. And this prediction is based on conventional, existing generator technology, not the exotic, high-efficiency methods excitingly described by Drs. Rosa and Jackson of AvCo Research Labs this afternoon -- as well as by Roe.

Mr. McGuire of Minnesota Power and Light, and Robert Pedersen of the Northern Pacific reminded us that Montana coal already is going to distant generating plants, by 10,000-ton, unitized trainloads, with the prospect of significant increases in future tonnages. And a number of representatives from power distribution systems showed that our coal supply already is being considered for use in the near future by other consumers -- either by unit-train transportation described by Mr. Pedersen, or by slurry pipelines described by Mr. Wasp of Bechtel Corporation, or by conversion to synthetic fuels by processes like those described by Dr. Johnson.

As to competition of Montana coals with others, Mr. Phelps showed how strip mining wins out over shaft mining in higher recovery and lower costs. Neil Adams compared this state's 8-to 10-cents-per-million BTU production costs to the 20-cents-per-million for Missouri's dwindling supply. And Ken Holum pointed out that nuclear plants still require a third more capital investment than fossil-fueled plants.

But the commercial exploitation of most raw materials -- with coal no exception -- invariably brings, or is accompanied by problems of which many of our speakers, particularly this second day, made us aware. For one thing, it always exerts influence on the environment in a variety of ways -- some of them undesirable -- and Montana Power Company President O'Conner reminded us we have to consider the effect on this environment not only of making use of our coal, but also the failure to do so. Keynoter Freeman described pollution as a by-product of affluence, not poverty. And much of the time this morning was spent on elaboration of the factors involved in preserving, or even enhancing the physical environment.

We heard both sides of the argument for voluntary or legally imposed requirements on both pollution restriction and reclamation. But the terms used time and again were "foresight" and "reasonableness" and "balance". Congressman Melcher this noon called for, among other things, a balance of research programs. Ted Schwinden of the State Lands Commission called attention to the emotional effects of changes in land use, and the responsibility of government to minimize the inflamed feelings. Representative Christensen pointed to a change in the attitudes of responsible industry toward preservation of the environment; although, he said, we are entitled to the protection of such measures as mandatory reclamation. Representatives of the coal and other industries indicated preference to have and to abide by reasonable restrictions -- and volunteered to impose restrictions on themselves as well.

Some of the other problems dealt with in the Symposium were the provision of necessary water supplies for coal conversion,

power generation, and other industrial uses.

Another was the need for recognition of Montana coal lands as sources of valuable scientific and archeological information, which should be obtained before the potential sites were obliterated by strip or other mining.

Another was the location of funds to finance massive programs of development.

Still another was the necessity of careful, comprehensive planning recognizing the complex interrationship of systems in the totality of the region. Mr. Darrow made an eloquent plea for such careful study.

But the outstanding mood of the Symposium I feel (and I'm sure you will agree) was optimism; the expectation of abundant returns to the economy of the state through careful use of a great natural resource, combined with technological breakthroughs in fuel conversion, power generation, and transmission of energy -- and which in themselves seem to give promise of solutions to some of the very problems of preservation of the environment, the need for more tax revenue described by Senator McGowan and the problems of poverty, economic instability and so on that are of so much concern to Montanans.

It's all a large order -- and most assuredly state government as well as federal government and industry itself has an important role to play.

While I can't speak for all state departments, I know that some state agencies are implementing programs that meet in part some of the needs expressed these two days:

1. The Governor's Advisory Council on Natural Resources has 18 members representing the natural resource related agencies of state government. A special committee of the Council reviews and examines contracts under the 1967 and 1969 Mining Land Reclamation Laws to develop suggestions reflecting both economic and environmental considerations of the member agencies. This Symposium, I'm sure has helped us greatly in this task.

2. Legislative Joint Resolution #18 -- 41st Legislative Assembly. The 41st Montana Legislature was aware of the economic importance of the vast coal deposits of eastern Montana, and of the significance of available water supplies to the development of this resource. The Legislature, through Senate Joint Resolution No. 18, intended to keep itself informed of all current plans to develop Montana's coal resources. The Legislature, therefore, resolved:

   (1) That the Water Resources Board would keep the Legislative Council informed of progress on the development of Montana's coal resources and of any agreements contemplated which might affect water to be used from the drainage areas of the Yellowstone, Bighorn, Little Bighorn, Tongue, Powder, and Musselshell Rivers;

   (2) That the Water Resources Board would keep the Legis-

lative Council informed of any basis of priorities upon which applications for water use from the above drainages shall be judged; and

(3) That the Legislative Council assist the Water Resources Board in any manner it deems advisable in the compilation of data on the use of water to develop coal resources.

The Water Resources Board has employed the Bechtel Corporation of San Francisco to study the feasibility of increasing storage in the Tongue River Reservoir. Bechtel concluded that it would be feasible to build the High Tongue River Dam, thereby increasing the total firm yield of the reservoir to 100,000 acre-feet. The additional 60,000 acre-feet will be available for the development of Montana's coal resources. The Water Resources Board has expressed a willingness to negotiate with companies that are interested in executing "options" and purchase contracts for Tongue River water, and several companies have affirmed their desire to pursue discussions and negotiations which could lead to such agreements.

3. Governor Anderson has proposed a Regional Multi-State Development Commission to:

   A. Improve the economic and social well-being of the rural and urban areas within the Region through:

      (1) full development of recreational potential and tourism;

      (2) improvement of transportation to effect lower freight costs and increased trade;

      (3) utilization and full development of natural and human resources;

      (4) an improved economic base to halt out-migration, raise median family income, and provide additional job opportunities; and

      (5) enhance the quality of life within our environs.

   B. Provide for orderly growth through the partnership of the federal government, states, cities, counties, multi-county development groups, universities, and so forth.

   C. Establish overall policy and direction of governmental programs to prevent overlapping and cross-purposes, and to provide consistent and relevant policy to meet the needs of these Great Plains states.

4. The Eastern Montana Economic and Social Development Conference showed its participants that any success its groups would have depends directly on the participation and involvement of all its citizens.

While these activities fall short of what Bill Warne called for in the establishment of "an executive commission responsible for both directing and controlling the use of the state's coal

reserves", they seem to be in steps in the right direction and certainly if my reading is correct, in tune with the new mood, so well expressed by nearly all speakers, for achieving development under optimum environmental conditions.

It's my own feeling, I'm sure shared by many others, that we can have, as suggested by Congressman Melcher, cows and sheep, and deer and elk, and still bring about a better urban-rural balance.

CONCLUDING REMARKS

Vic Reinemer

In his keynote address Dave Freeman said, "If I can sound a keynote for your Symposium, it's to concentrate on the followup actions that we can take as government officials, utility executives, university professors, equipment manufacturers, conservationists, or just interested citizens."

I would like to very briefly mention five items of the follow-ups that will in a way involve the federal government and you and the other categories mentioned by me.

I think that number 1, it came through loud and clear that the research and development policies of the federal government are badly out of proportion. We are putting more than $2 billion (of federal tax funds) into nuclear research, and peanuts into coal research.

The Senate Interior Subcommittee on Minerals and Materials and Fuels, which is headed by Senator Moss of Utah, is now completing hearings on the energing energy technology. The purpose of this hearing, and also a purpose of this Symposium, is to give visability and to give it in Washington, a few blocks away from the Budget Bureau, to the need for getting our Research and Development funds into balance.

Industry can help here in two ways. First, in re-evaluating its own R and D programs, and secondly in letting your views be known to your own members of Congress regarding the need for making meaningful the appropriations for the Office of Coal Research.

Secondly, Ken Holum and Bill Warne emphasized the need for a really integrated transmission system. As Ken Holum put it, "We must understand that the economic feasibility of using Rocky Mountain coal delivered by wire to serve these large and growing loads requires that we achieve the economies and efficiencies inherent in large generating stations and high voltage transmission systems." I make a comparision to the Interstate systems. In some respects our transmission system is like an Interstate highway interspersed with gravel roads, detours, and a few unbuilt bridges. We need a kind of cooperation between private power companies and the federal government, as we see most recently in California, to get on with this tremendously vital transmission integration program.

Third, the matter of siting of steam plants. I noticed by this mornings Gazette, the front page story, that the National Coal Policy Conference is going to have to update the map which we saw out here on plants being considered, planned, or under construction. Montana Power (this wasn't an official announcement, but it was up-and-up) has shown some indication that the Company does plan an additional large steam plant at a site as yet undetermined. I think that those of us who have been following the fights that are going on in Minnesota, and in Vermont especially,

Vic Reinemer, Executive Secretary to Senator Lee Metcalf, Senate Office Building, Washington, D.C.

on the siting of nuclear plants, recognize the vehemence of concern regarding siting of facilities which do add to pollution. And if I correctly heard the panels of this Symposium, they indicated that some people, public and private, want to be included in the decision-making process regarding the siting of coal-burning plants, and that if adequate procedures are not worked out at the state level they will be requested at the federal level.

Fourth, I want to mention especially for the benefit of the university people (and we have four units of the University of Montana system represented here on the Symposium) the availability of some research grants that I think will help to further the goals of all of us here at the Coal Symposium. National Science Foundation and some of the others are recognizing that they have made relatively few grants to the western universities. They have been reminded of that very strongly by a number of western Senators, and I think they would be quite receptive to grant proposals. One thing that came out of this Symposium was the idea for a very practical bit of research over at the University of Montana. Gene Pike, Manager of Missoula Electric, says that the sulfur which hangs heavy in the atmosphere over in that temperature inversion area in Missoula is eating up his copper wires, and I think that this is something that needs a little bit of attention.

My fifth point we didn't intend to really deal with at this Symposium. It boils down to this -- we say we are going to mine and we are going to also protect the environment. But how are we going to pay for this protection of the environment. Reference was made to the severence tax by several speakers and particular reference to S910, a bill by Senator Metcalf regarding a severence tax. In about three minutes I just want to tell you what this is all about. Historically, of course, the severence tax is a state tax with widely varying applications. In Florida, for example, they have a model 5% severence tax on oil and gas (which they do not produce), but no severence tax on phosphate (which is the principal mining industry of the state). In the Appalachian states, where coal is mined heavily, you will not find a severence tax. You will find a coal severence tax in states where there is no significant mining of coal. In Louisiana there is a state severence tax on oil and gas. The tax amounts to more than 5%, which provides more than a quarter of a billion dollars of revenue annually to the state of Louisiana. Here is an instance where you have certainly a state which is not anti-industry, but which imposes a heavy severence tax on oil and gas.

Our bill S910 is an attempt to provide the states with the revenue that they have not been able to get because of the effectiveness of the lobbies of these particular state legislatures. The way it would work would be this: in those states where there is a state severence tax the operator of course would pay no additional tax. In those states where they don't have a state tax, the federal government would collect the 5% tax and that would be turned over in its entirety to the state government upon passage of enabling legislation at the state level. So when this became fully operative the federal government would not keep any money at all from this tax and the full sum of some $600 million would go to the states, there to be used for reclamation and for pollution abatement. I would like to emphasize that we're not wedded to this particular approach. Senator Metcalf regards this

as an initial pleading. Another proposal that has not yet been introduced, I don't know if it will be, is getting some consideration in the administration, is a simple levy of a 1% tax at the well or at the mine. The money would then be available for research as well as reclamation.

Our whole point is that we hope that our bill and some of these other proposals will become the focal point from which to build a tax policy with which industry can live and which will permit all of us to live, to breath air freely, to drink water safely, without fear that we have failed as stewards during this most precarious journey that earth has yet taken.

In conclusion, on behalf of the sponsors of the Symposium, this exhausting yet exhilerating Symposium, I want to pay a special thanks to Eastern Montana College and its President Heywood and especially to the person who is also a great folksinger, though we didn't give him a chance to entertain because he was so busy, but Montana greatest resource, greatest human resource in my book, Dr. Will Clark who really kept this thing going. And we are all going to have to get up anyway to end this Symposium, and I don't know any better way than in a rising ovation to Will Clark.